RACOM
RADIO DATA NETWORKS

User manual

RAy2 Microwave Link

fw 2.1.x.x
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version 1.13

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Table of Contents

List of Tables

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- Due to the nature of wireless communications, transmission and reception of data can never be guaranteed. Data may be delayed, corrupted (i.e., have errors), or be totally lost. Significant delays or losses of data are rare when wireless devices such as the RAy2 are used in an appropriate manner within a well-constructed network. RAy2 should not be used in situations where failure to transmit or receive data could result in damage of any kind to the user or any other party, including but not limited to personal injury, death, or loss of property. RACOM accepts no liability for damages of any kind resulting from delays or errors in data transmitted or received using RAy2, or for the failure of RAy2 to transmit or receive such data.
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Quick guide

Accessing units

— Default IP addresses: **192.168.169.169/24** (L unit) Username: admin
192.168.169.170/24 (U unit) Password: admin
Set computer IP address within the IP range 192.168.169.1-255.

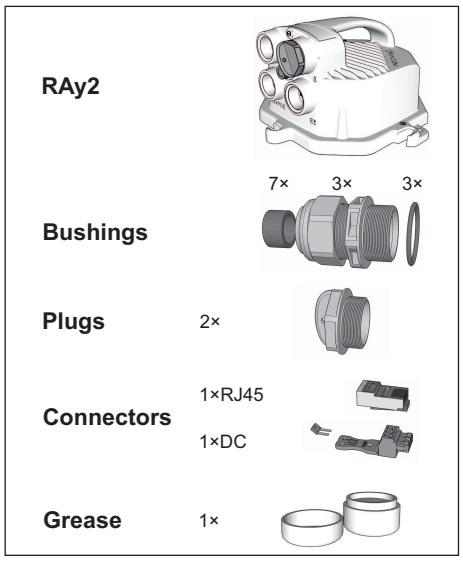
— Web browser access – https://192.168.169.169 (L unit)
or https://192.168.169.170 (U unit).
Accept the https security certificate issued by RACOM.

— If the units are linked to each other, the status indicator in management interface states “OK” and status LED “AIR” lights green. If not, utilize the antenna alignment. (see pict. 11)

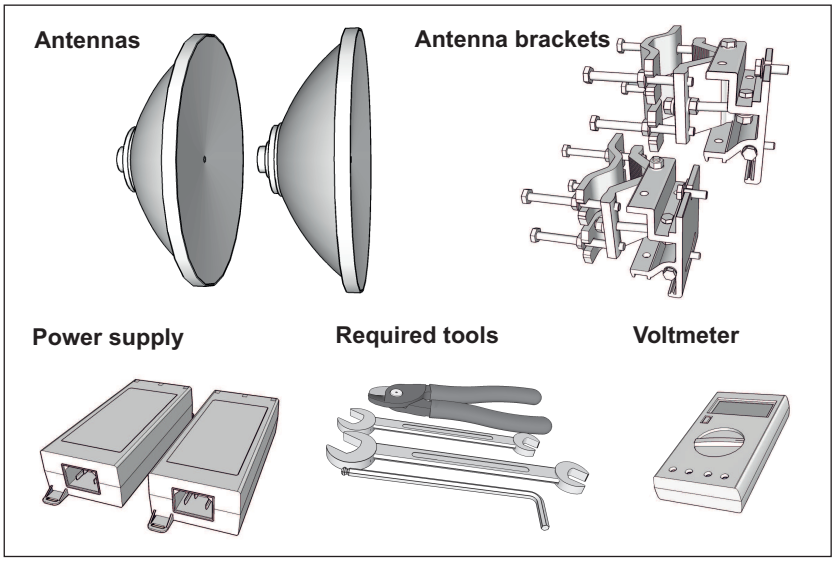
Configuration and backup of basic parameters

Set bandwidth, TX/RX channel, TX modulation, RF power, **IP addresses** (do not use the default ones), **Access channels** (ssh, https, …).
Reboot both units and check the link status (to verify that the parameters are saved correctly)
Backup the configuration in the *Tools* – *Maintenance* – *Backup* – *Settings* menu.
Store the backup file to your PC.

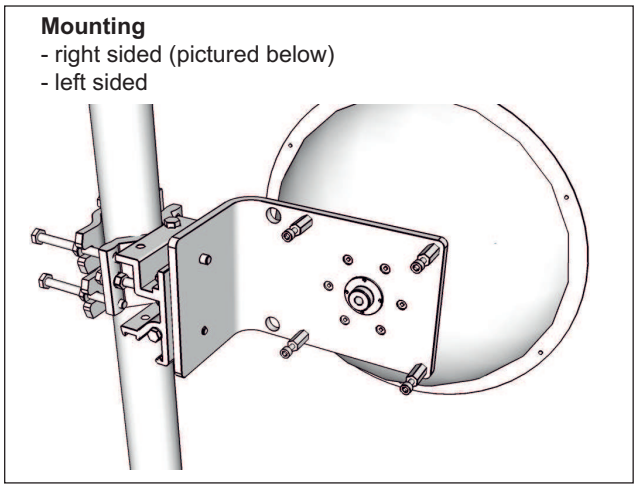
1. Delivered items



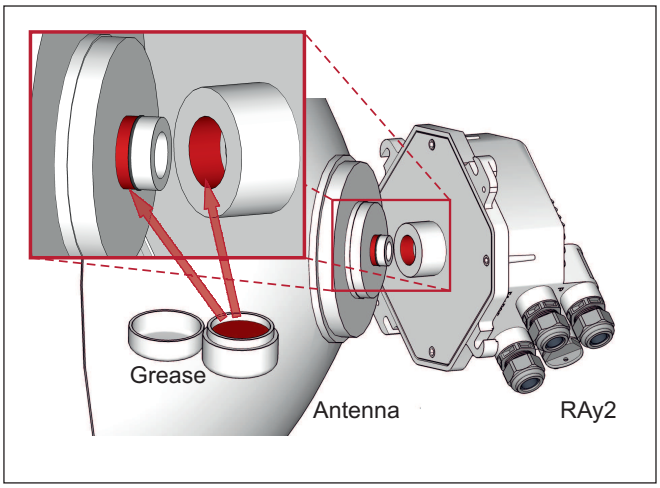
2. Accessories



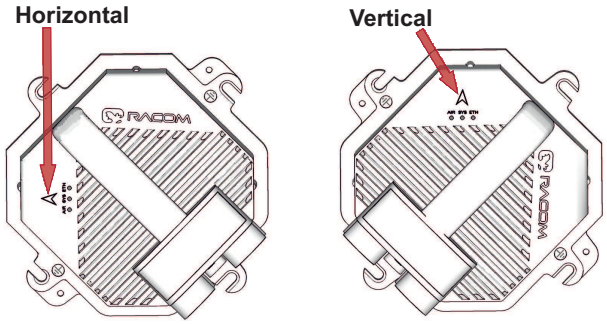
3. Bracket and antenna mounting



4. RAy unit and antenna lubrication



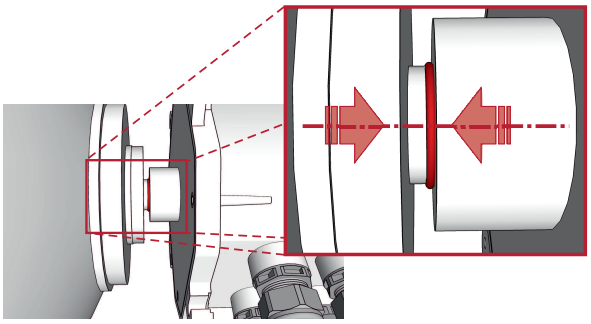
5. Unit polarization



RAy2-10, RAy2-11
- the same polarization for both units

RAy2-17, RAy2-24
- cross polarization
- one side – horizontal
- the other side – vertical

6. Unit installation

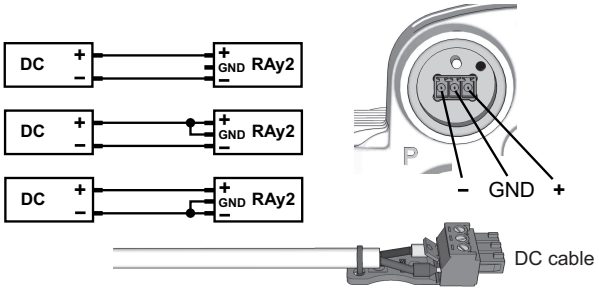


Check the correct O – ring placement on the antenna

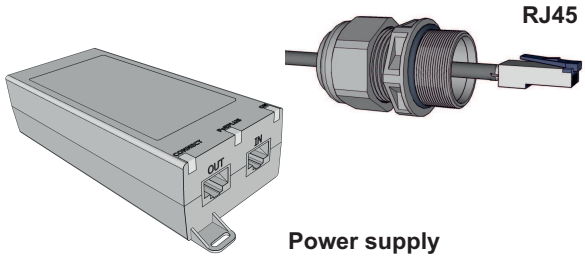
Ensure the antenna and unit are carefully aligned

Do not use excessive force!

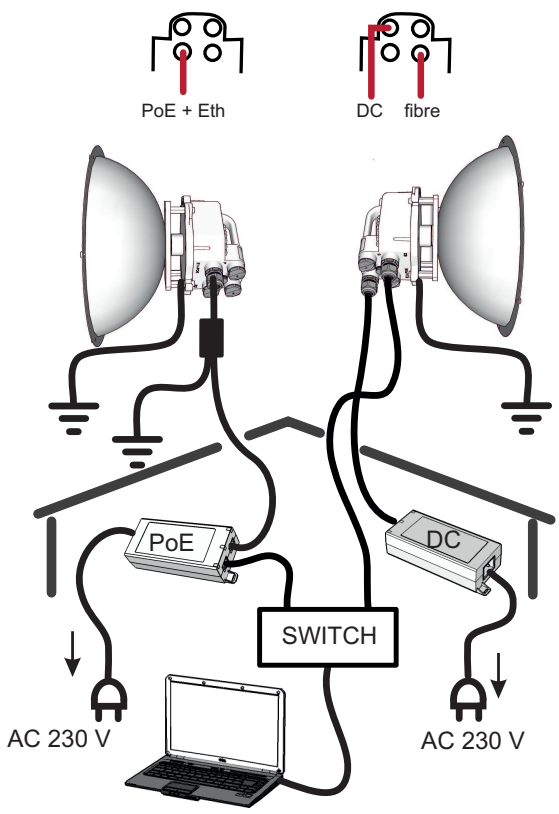
7. Power - DC



8. Power - PoE

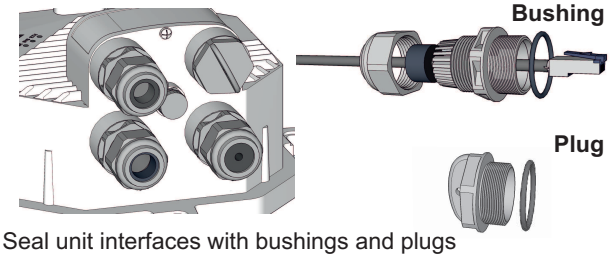


9. Power grounding and connections



Units must be grounded
For surge protection - see user manual

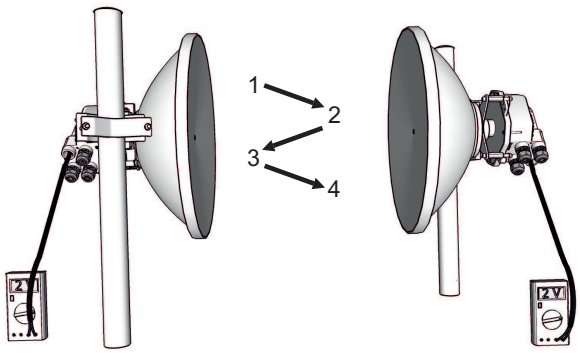
10. Sealing



Seal unit interfaces with bushings and plugs

11. Antenna alignment

Hint: Set QPSK, CS 7 MHz, max. TX power
Step-by-step alignment – see user manual



Best RSS = minimum voltage in range 0–2 V

ver. 1.7

List of documentation

User manuals

- **Microwave Link RAy2** - this document
  User manual RAy2-10, RAy2-11, RAy2-17, RAy2-24
- **Microwave Link RAy11, 17, 24**[1]
  User manual RAy11, RAy17, RAy24
- **Microwave Link RAy10**[2]
  User manual RAy10

Datasheets

- **RAy2 - Datasheet**[3]
- **RAy - Datasheet**[4]
- **RAy - SCADA Backbone**[5]

Application notes

- **RAy - Application notes**[6]

Contents of the box

- 2 pc RAy2
- 2 pc Cable bushing set, connectors
- 1 pc Grease marked "SILIKONOVE MAZIVO"

[1] http://www.racom.eu/eng/products/m/ray17/index.html
[2] http://www.racom.eu/eng/products/m/ray/index.html
[3] http://www.racom.eu/download/hw/ray/free/eng/00_letaky/datasheet_RAY2_en.pdf
[4] http://www.racom.eu/download/hw/ray/free/eng/00_letaky/datasheet_RAY_en.pdf
[5] http://www.racom.eu/download/hw/ray/free/eng/00_letaky/leaflet_RAY_scada_en.pdf
[6] http://www.racom.eu/download/hw/ray/free/cz/01_ray/RAy-AppNote-en.pdf

1. RAy2 – Microwave Link

The microwave link RAy2 is designed as a high-speed point-to-point wireless bridge for data transmission under the latest requirements of modern wireless transmission equipment.

RAy2 works with an ethernet interface and can be used in backhaul networks as well as a last-mile terminal.The design of microwave link RAy2 reflects effort on meeting the strictest criteria of ETSI standards, particularly for durability against interference, high receiver sensitivity and high output power to achieve maximum link distance. The native gigabit Ethernet interface is able to cope with full speed user data throughput at low latency. High availability of the link (up to 99.999%) is able to be achieved using hitless Adaptive coding and modulation. RAy2 microwave links can also be operated as a Short Range Device (SRD).

The link properties can be summarised as:

- High data throughput
- Spectrum effeciency
- Robustness
- Security - cofiguration via http, https, ssh
- User friendly interface, advanced diagnostics

Key technical features see Chapter 10, *Technical parameters*

Note

Operation of the RAy2-xx is described in this user manual.
Operation of the RAy11, RAy17 and RAy24 is described in User Manual RAy11,17,24[1].
Operation of the RAy10 is described in the RAy10 User Manual[2].

[1] http://www.racom.eu/eng/products/m/ray17/index.html
[2] http://www.racom.eu/eng/products/m/ray/index.html

2. Implementation Notes

2.1. Link calculation

Before a microwave link can be installed, an analysis and calculation of the microwave link must be made first. The analysis should take place before the site survey itself to get a clear idea about the dimensions of the antennas. The analysis consists of the following steps:

- Free space loss calculation
- Link budget calculation
- Rain attenuation
- Multipath fading
- Fade margin
- Fresnel zones calculation

This chapter explains the individual steps and an example of link design is given at the end.

NOTE - For quick reference you can use the calculator on www.racom.eu[1]

2.1.1. Free space loss calculation

As the electromagnetic waves travel through open space they are attenuated. This attenuation is described as Free-space Loss. The loss depends on the distance travelled by signal and its frequency. Longer distance and higher frequency both mean greater attenuation. Free-space loss can be calculated thus:

$FSL = 32.44 + 20\log f + 20\log D$

Where:

FSL free-space loss (dB)

f frequency of the emitted signal (MHz)

D length of the link (km)

2.1.2. Link budget calculation

The goal is to design a link producing a received signal stronger than the receiver's sensitivity at the required BER (typically 10^{-6}). Since every radio signal in earth atmosphere is subject to fading, some difference between received signal level under normal circumstances and receiver sensitivity is needed to serve as a fade margin. The minimum value of fade margin can be calculated from the requirement for link availability (e.g. 99.999% of the time). The required margin depends on the length of the link as well as other factors such as rain attenuation, diffraction and multipath propagation.

If we ignore the additional loss along the path, the received signal strength can be calculated using the formula for signal propagation in free space as follows:

$P_R = P_T + G_T + G_R - FSL$

Where

[1] http://www.racom.eu/eng/products/microwave-link.html#calculation_obsah

P_R received power level (dBm)

P_T transmitted power (dBm)

G_T transmitting antenna gain (dBi)

G_R receiving antenna gain (dBi)

FSL free space loss (dB)

P_R must be:

$P_R > P_S$

Where:

P_S receiver sensitivity (dBm)

The receiver's sensitivity defines the minimum level of the received signal at which the receiver is able to process the signal without losses or affecting the transmitted data (for BER better then 10^{-6}).

2.1.3. Fade margin

Determining sufficient fade margin is the most important step in microwave link design. If the margin is too small, the link will be unstable – as a result, sufficient availability of the link or quality of the provided services cannot be guaranteed. On the other hand, unnecessarily large margin makes the link more expensive (higher performance, larger and more expensive antennas) and increases the cost of creating the microwave link.

The following paragraphs describe the two most significant types of signal strength loss – rain and multipath attenuation, which are the most frequent along with free space loss. Mutual relation between rain and multipath attenuation rules out the possibility that the link could be affected by both types of attenuation at the same time – **these types of attenuation do not add up**. To determine the fade margin it is necessary to calculate both rain and multipath attenuation. The larger of the two types of attenuation determines the value of fade margin. In areas with high precipitation, rain attenuation can be expected to be more prominent. By contrast, links located in drier climates and little inclination, will suffer more from multipath attenuation.

2.1.4. Rain attenuation

For frequencies of about 10 GHz rain attenuation starts to become increasingly effective. Precipitation is not identical in all areas which is why ITU released a recommendation Rec. ITU-R PN.837-1 for splitting the world into 15 regions according to precipitation intensity see Fig. 2.1, for more detail Appendix B, *Rain zone map*. In the areas with higher precipitation greater rain attenuation must be expected and a greater signal fade margin must be established; see the calculation of link availability.

The following properties are inherent to rain attenuation:

- It increases exponentially with rain intensity
- It becomes significantly larger as the distance travelled increases (>10 Km)
- Horizontal polarization causes greater rain attenuation than vertical polarization
- Rain outage increases dramatically with frequency and path length

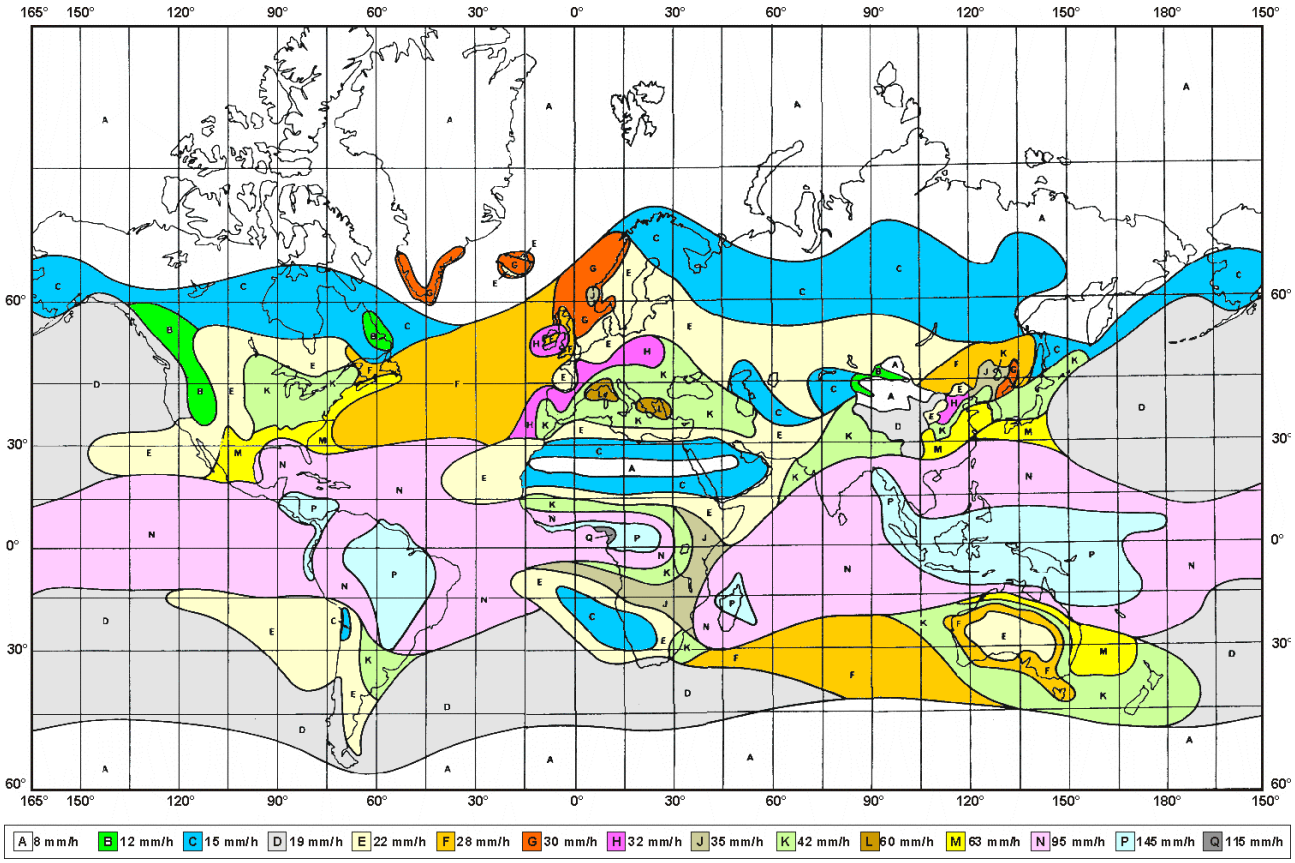


Fig. 2.1: Rain zone map, based on Rec.ITU-R PN.837-1

Rain attenuation can be calculated using ITU-R outage model, which consists of the following:

Obtain the rain rate $R_{0.01}$ exceeded for 0.01 per cent of the time (with an integration time of 1 min). $R_{0.01}$ values are defined for 15 rain zones and different time percentages and they are given in ITU-R Recommendation P.837.

Tab. 2.1: Rain rate R (mm/h) ITU-R P.837

Percentage of time (%)	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
1.0	<0.1	0.5	0.7	2.1	0.6	1.7	3	2	8	15	2	4	5	12	14
0.3	0.8	2	2.8	4.5	2.4	4.5	7	4	13	42	7	11	15	34	49
0.1	2	3	5	8	6	8	12	10	20	12	15	22	35	65	72
0.03	5	6	9	13	12	15	20	18	28	23	33	40	65	105	96
0.01	8	12	15	19	22	28	30	32	35	42	60	63	95	145	115
0.003	14	21	26	29	41	54	45	55	45	70	105	95	140	200	142
0.001	22	32	42	42	70	78	65	83	55	100	150	120	180	250	170

Compute specific attenuation γ_R (dB/km) for the frequency, polarization, specific rain rate using ITU-R recommendation P.838. Rain attenuation for rain rate $\gamma_{R_{0.01}}$ can be calculated as follows:

$$\gamma_{R_{0.01}} = k_{h,v} . R_{0.01}^{\alpha^{h,v}}$$

where:

$k_{h,v}$, $\alpha_{h,v}$ constants for horizontal and vertical polarization. Constants are slightly different for each polarization, see next table according to ITU-R P.838

Tab. 2.2: Constants k, α for horizontal and vertical polarization at 10, 11, 17 and 24 GHz

	k_h	α_h	k_v	α_v
10 GHz	0.01	1.26	0.01	1.22
11 GHz	0.02	1.21	0.02	1.16
17 GHz	0.06	1.09	0.07	1.01
24 GHz	0.14	1.01	0.14	0.96

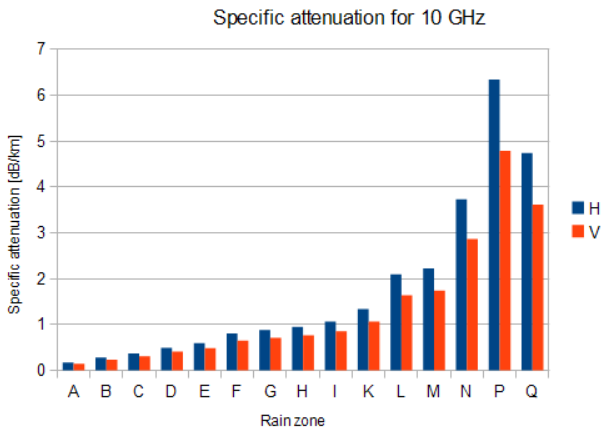


Fig. 2.2: Attenuation for 10 GHz, polarization H, V

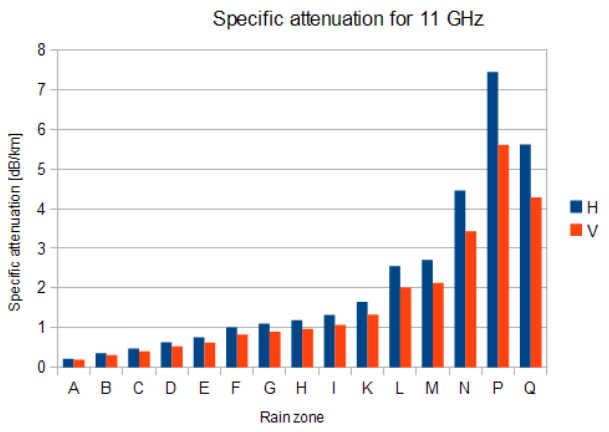


Fig. 2.3: Attenuation for 11 GHz, polarization H, V

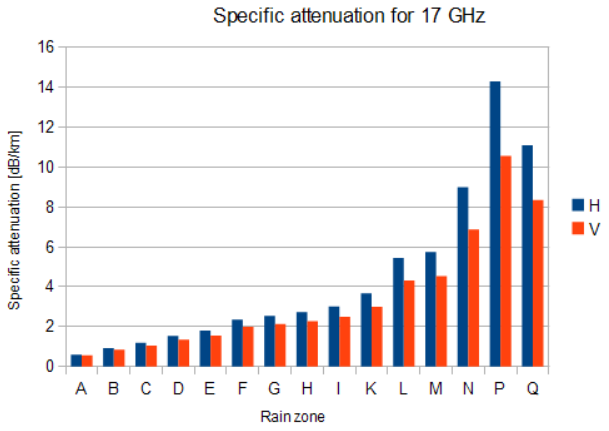


Fig. 2.4: Attenuation for 17 GHz, polarization H, V

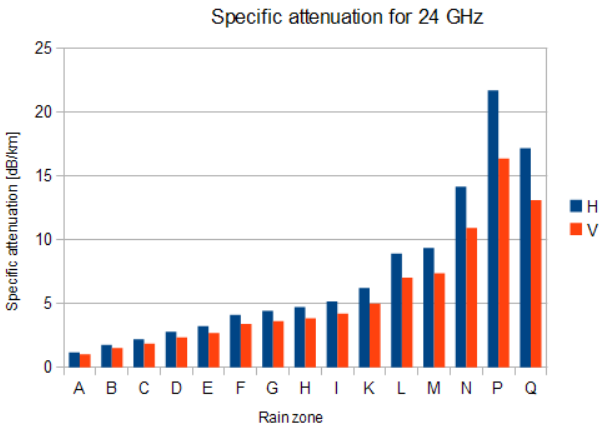


Fig. 2.5: Attenuation for 24 GHz, polarization H, V

Fig. 2.2 shows that rain attenuation is greater for horizontal polarization. In regions with higher precipitation the difference in attenuation is more marked. The microwave links RAy17 and RAy24 use both polarizations, hence the need to consider the worse of the two, i.e. horizontal polarization. When ACM

is active we recommend using horizontal polarization in the direction with lower data traffic (typically up-link).

2.1.5. Multipath fading

Multipath fading is another dominant fading mechanism. A reflected wave causes a phenomenon known as multipath, meaning that the radio signal can travel multiple paths to reach the receiver. Typically, multipath occurs when a reflected wave reaches the receiver at the same time in opposite phase as the direct wave that travels in a straight line from the transmitter.

Multipath propagation gives rise to two kinds of signal degrading effects, i.e., flat fading and frequency selective fading. Flat fading is a reduction in input signal level where all frequencies in the channel of interest are equally affected and is dependent on path length, frequency, and path inclination. In addition, it is strongly dependent on the geoclimatic factor K.

To calculate the probability of outage due to multipath propagation of microwave links the ITU-R probability model can be used which describes a single frequency (or narrowband) fading distribution suitable for large fade depths A in the average worst month in any part of the world (based on ITU-R P.530-14). The calculation for detailed link design is given as follows [1]:

$$P_0 = Kd^{3.4}(1+|\varepsilon_P|)^{-1.03}f^{0.8}\times 10^{0.00067h_L - A/10}$$

where:

d link distance (km)

f frequency (GHz)

h_L altitude of lower antenna (m)

A fade depth (dB)

K is geoclimatic factor and can be obtained from:

$$K = 10^{-4.6-0.0027dN1}$$

The term dN1 is provided on a 1.5° grid in latitude and longitude in ITU-R Recommendation P.453. The data are available in a tabular format and are available from the Radiocommunication Bureau (BR). E.g. in Central Europe the values dN1 range from -242 to -362.

From the antenna heights h_e and h_r (meters above sea level), calculate the magnitude of the path inclination $|\varepsilon_P|$ (mrad) using the following expression:

$$|\varepsilon_P| = \frac{|h_r - h_e|}{d}$$

where:

d link distance (km)

h_r, h_e antenna heights above sea level (m)

2.1.6. Fresnel zones calculation

The position of obstacles between points of the bridge can significantly influence the quality of the microwave link. The radio signal doesn't only radiate along the line of sight, but also in the area around it, i.e. in the so-called 1st Fresnel zone. Within this zone 90 % of the energy is transmitted between the transmitter and receiver antenna. This space has the shape of an ellipsoid. If it is disturbed the link has poorer transmission properties and a higher quality antenna is required. For this reason the position of the antenna can be just as important as its height above ground. 60 % of the 1st Fresnel zone is considered as the most important.

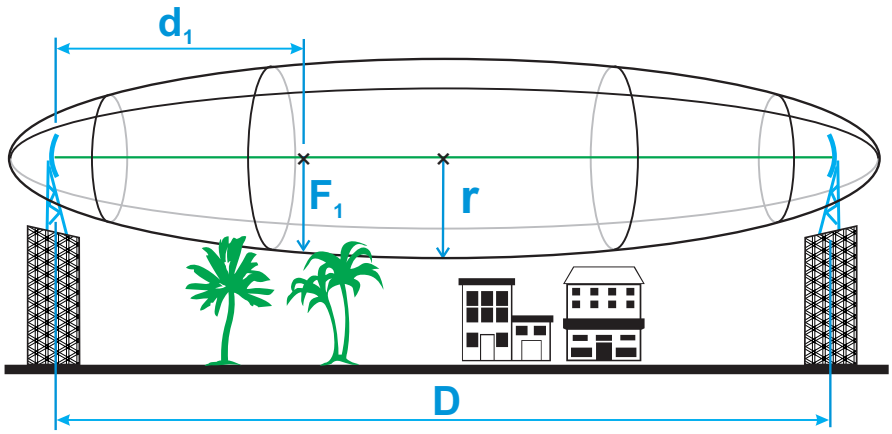


Fig. 2.6: Fresnel zone

The general equation for calculating the first Fresnel zone radius at any point P in between the endpoints of the link is the following:

$$F_1 = \sqrt{\lambda \frac{d_1 . d_2}{d_1 + d_2}}$$

Where:

F_1 first Fresnel Zone radius in metres

d_1 distance of P from one end in metres

d_2 The distance of P from the other end in metres

λ wavelength of the transmitted signal in metres

The cross sectional radius of each Fresnel zone is the highest in the center of link, shrinking to a point at the antenna on each end. For practical applications, it is often useful to know the maximum radius of the first Fresnel zone. From the above formula, calculation of the first Fresnel zone can be simplified to:

$$r = 8.657\sqrt{\frac{D}{f}}$$

where:

r max radius of first Fresnel zone (m)
reducing the radius to 60% get values listed in the following table that define the space particularly sensitive to the presence of obstacles

D total link distance (km)

f frequency (GHz)

Tab. 2.3: 60 % of the 1st Fresnel zone

Length of link D	Radius of zone r for frequency		
	11 GHz	**17 GHz**	**24 GHz**
0,5 km	1.10 m	0.89 m	0.75 m
1 km	1.56 m	1.25 m	1.06 m
2 km	2.21 m	1.77 m	1.50 m
4 km	3.13 m	2.50 m	2.12 m
6 km	3.84 m	3.07 m	2.60 m
8 km	4.43 m	3.54 m	3.00 m
10 km	4.95 m	3.96 m	3.35 m
15 km	6.06 m	4.85 m	4.10 m
20 km	7.00 m	5.60 m	4.74 m
50 km	11.07 m		

2.2. Example of microwave link design

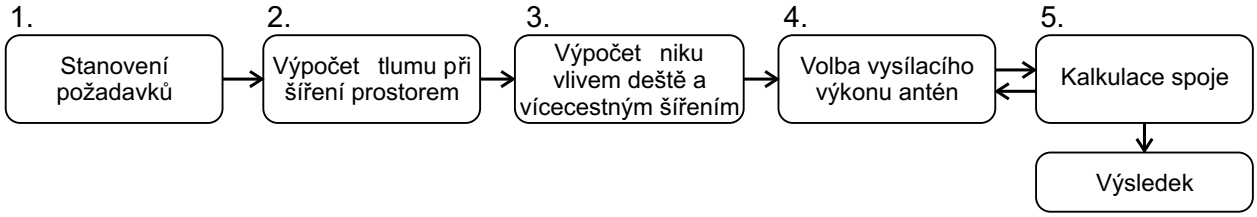


Fig. 2.7: Design flowchart

Step 1 - Requirements Determination

Link parameters:

Link distance: 4 km

First antenna height above sea level: 295 m

Second antenna height above sea level: 320 m

Location: Central Europe (rain zone H, refraction gradient dN1= −300)

Transmission requirements:

Required data rate: >160 Mbps

Required availability: 99.99 %

RAy parameters:

17 GHz

161 Mbps -> Modulation 16QAM; BW=56 MHz; P_S(BER 10^{-6})= −79 dBm

Tx power +5 dBm (max. Tx power)

Antenna gain:

30 cm ... 32.2 dBi

60 cm ... 37.8 dBi

99 cm ... 42 dBi

Step 2 - Free space loss calculation

FSL = 32.44 + 20log f + 20log D = 32.44 + 20log17.2·10^3 + 20log4 = 129.1 dB

Step 3a - Rain attenuation

For 99.99% availability in rain zone B the rain rate is $R_{0.01}$=32 (see Fig. 2.1)

For f=17 GHz k_h=0.06146; α_h=1.0949; k_v=0.06797; α_v=1.0137

Vertical polarization:

$\gamma_{R0.01} = k_v \cdot R^{\alpha_v}_{0.01} = 0.07 \cdot 32^{1.01}$ = 2.32 dB/km => for 4km distance 9.3 dB

Horizontal polarization:

$\gamma_{R0.01} = k_h \cdot R^{\alpha_h}_{0.01} = 0.06 \cdot 32^{1.09}$ = 2.62 dB/km => for 4km distance 10.5 dB

Step 3b - Attenuation due to multipath propagation

We have to find required fade margin for reliability of the link 99.99 percent.

Path inclination:

$$|\varepsilon_P| = \frac{|h_r - h_e|}{d} = \frac{|295 - 320|}{4} = 6.25\,mrad$$

The percentage of time that fade depth A (dB) is exceeded in the average worst month is calculated as:

$P_0 = Kd^{3.4}(1+|\varepsilon_P|)^{-1.03}f^{0.8}\times10^{0.00067h_L-A/10}$

$P_0 = 10^{-4.6-0.0027\times(-300)}\times4^{3.4}(1+|6.25|)^{-1.03}17.2^{0.8}\times10^{0.032\times10-0.00067\times295-A/10}$

$P_0 = 0.022871\times10^{-0.19765-A/10}$

For reliability 99.99% is P_0=0.01 we get exponential function for A:

A = -0.19765 - 10log(0.01/0.022871) = 3.4 dB

The minimum fade margin required to suppress multipath fading on this link would be 4 dB.

Step 4 - Choice of Tx power and antennas

Step 5 - and Link budget calculation

Calculation in steps 3a and 3b determines the minimum fade margin required for stable link operation as 11 dB (rain attenuation is dominant). If you use the maximum performance of antenna with diameter of 30 cm, complete the radio formula as follows:

$P_R = P_T + G_T + G_R - FSL$ = 5 + 32.2 + 32.2 − 129.1 = −59.7 dB

Fade margin:

$A = |P_S| - |P_R|$ = 79 − 59.7 = 19.3 dB

The resulting fade margin is larger than the required 11 dB. Current legislation in the Czech Republic allows maximum EIRP of +20, i.e. the sum of transmit power and antenna gain at the transmitter can be 20 dB at the most. For 99cm antennas, TX power can be up to 20 - 42 = -22 dB, the resultant equation is as follows:

$P_R = P_T + G_T + G_R - FSL$ = -22 + 42 + 42 − 129.1 = −67.1 dB

Fade margin:

$A = |P_S| - |P_R| = 79 - 67.1 = 11.9$ dB

Fade margin is now only 12 dB which corresponds to link availability > 99.99% of the time in a year.

Technical literature often gives the minimum fade margin of 20 dB. For very long links (more than 10 km) fade margin will, indeed, be approximately 20 dB. For shorter links, however, such large margin is not necessary. It is helpful to first conduct the calculation above to receive an idea of the attenuation affecting the link.

The result

To achieve the required transmission capacity and link availability for link distance of 4 km, transmit power -22 dBm and 99 cm antennas were selected for both sides of the link.

Sources for Chapter Chapter 2, *Implementation Notes*:

[1] Lehpamer, H.: Microwave transmission network, Second edition, ISBN: 0071701222, McGraw-Hill Professional, 2010.

ITU-R recommendation used:

- ITU-R P.453-10 – The radio refractive index: its formula and refractivity data
- ITU-R P.530-14 – Propagation data and prediction methods required for the design of terrestrial line-of-sight systems
- ITU-R P.837-1 and 6 – Characteristics of precipitation for propagation modelling
- ITU-R P.838-3 – Specific attenuation model for rain for use in prediction methods
- ITU-R P.310, ITU-R P.526, ITU-R P.676, ITU-R P.834, ITU-R P.835

3. Product

RAy2 microwave links enable transmissions in both bands requiring license fees and those that are free. They work as a point-to-point link in a full duplex setting with transfer speeds of up to 360 Mbps. Bandwidth can be configured from 1.75 up to 56 MHz. Modulation can be fixed or adaptive and can be adjusted from QPSK to 256QAM. RAy2 microwave links can also be operated as a Short Range Device (SRD).

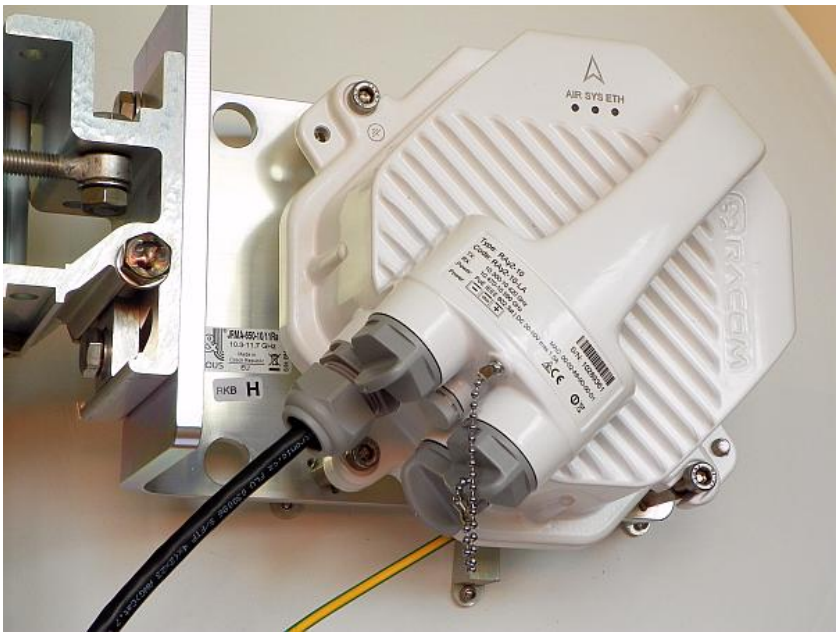


Fig. 3.1: RAy2 – Microwave link

The link is formed by two FOD (Full Outdoor) units. In the case of links operating in the RAy2-17 and RAy2-24 bands, both units have identical hardware. In the case of links operating in licensed bands, one unit (labeled L) is transmitting in the Lower and receiving in the Upper part of the band. The other unit (labeled U) is operating vice versa.

RAy2 links require the use of external parabolic antennas. Parabolic antennas from different producers are available.

Cross polarization - valid only for links operating in the RAy2-17 and RAy2-24 bands:

One side of the link uses one polarization for transmission (e.g. horizontal) and the opposite polarization for receiving (e.g. vertical). The other side of the link is turned by 90°. It therefore transmits and receives using opposite polarizations with respect to the other unit.

3.1. Mounting

Fig. 3.2: RAy2 Microwave link – antenna and FOD unit

The antenna is attached to the mast using a holder adjustable in two planes. The RAy2 unit is then mounted on the antenna.
There are two possible mounting positions – for horizontal and vertical polarization. Installation and adjustment of the holder is described in the Section 6.2, “Antenna mounting”.

Note

The RAy2-10 and RAy2-11 units must be mounted with the same polarization while the units RAy2-17 and RAy2-24 must be mounted with reverse polarity, see Cross polarization.

3.2. Connectors

Each unit is equipped with the following interfaces:

- ETH1+POE – Gigabit metallic Ethernet port. This port is capable of powering the unit with any Power over Ethernet power source working according to IEEE 802.3at standard.
- ETH2 – Slot for user exchangeable SFP module. A wide range of optical modules is available. Both single or dual mode transceivers can be used. An SFP module with metallic RJ45 interface can also be used.
  The SFP status LED is located just next to the slot.
- P – DC power connector.
  HW button for service purposes.
- S – USB service connector.
  RSS voltage output connectors.

Important

It is strongly recommended to use a high quality SFP module. The SFP modules listed in Accessories are thoroughly tested by RACOM and are guaranteed to function with RAy2 units. It is possible to use any other SFP module, but RACOM cannot guarantee they will be completely compatible with RAy2 units.

The SFP status LED function: The LED status is controlled directly from the SFP module. Its function is specific for each SFP module. The typical behaviour is an indication of the received signal strength. Should the signal be in the proper power range (not too strong and not too weak), the LED is shining.

Fig. 3.3: Connectors covered

Fig. 3.4: Connectors uncovered

Important

It is recommended that the ETH cable should be **grounded at both ends** of the connection. For example, the connector CON-RJ45-UBNT-CAT6 and ETH socket on the control panel should have a grounded sheath as should the connection to the RAy2 unit.

All bushings and plugs (including the original plugs in the ports) must be **fitted with O-rings** and carefully tightened. Otherwise, the unit is not protected against moisture intake and can not offer guaranteed functionality.

For detailed description see Connectors and Start up.

3.3. Power supply

The microwave unit can be powered either by PoE or a DC power source:

- **Standard PoE plus** (IEEE 802.3at) power source connected to the “ETH1+POE” connector. Supported voltage range is 40 — 60 V, distances up to 100 m. Internal RJ45 pins wiring is :
  - (V+) ... 1,2,4,5
  - (V-) ... 3,6,7,8

  It is possible to use all 8 pins or only 4 pins. Use:
  - either 4,5 (V+) and 7,8 (V-)
  - or 1,2 (V+) and 3,6 (V-)
  - or both simultaneously

- **Any kind of DC power source** connected to “P” 3-pin connector. Supported voltage range is 20 — 60 V.

Important

The microwave unit **doesn't support** a combination of both power supplies. Only one power supply can be connected at any one time.

The internal DC power source uses galvanic separation. If the galvanic separated power source is used and the DC power line needs to be grounded (either positive or negative wire), the middle pin of the 3-port DC connector can be used to make a connection between ground and the respective power wire, see Grounding options (d),(e). If grounding is required it should only be made in one of the following ways: on the DC power source side or using the 3-port DC connector plugged into the unit.

The next figure shows all available grounding options. We recommend the use of a galvanic separated power source and no additional DC grounding - see Fig. 3.5, “Grounding options” version c).

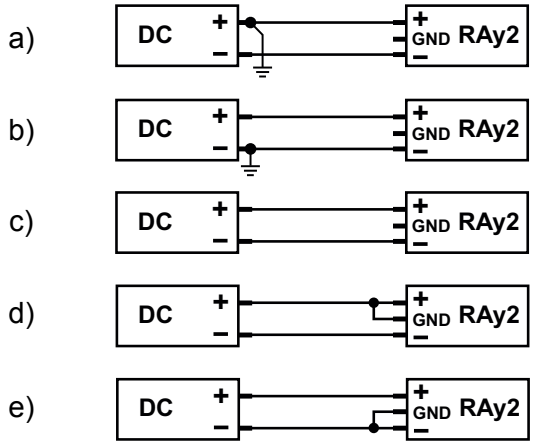


Fig. 3.5: Grounding options

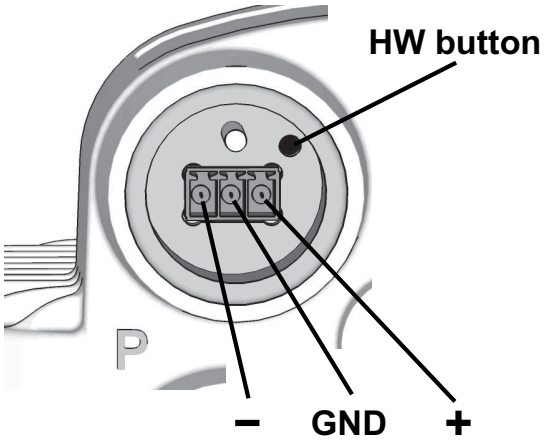


Fig. 3.6: Power supply connector 1

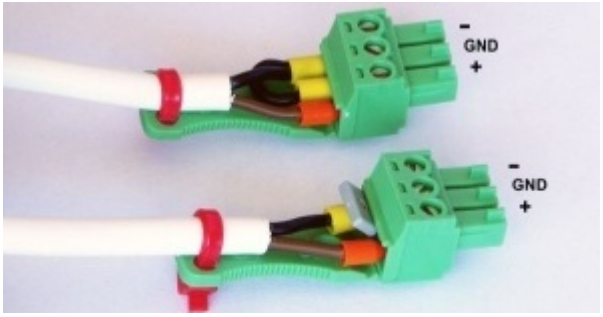


Fig. 3.7: Power supply connector 2

3.4. Status LEDs

Fig. 3.8: Status LEDs

Tab. 3.1: Meaning of LED status indicators

Diode	Colour	Function
AIR	Green	Permanently lit: AIR link OK
	Red	Permanently lit: AIR LOSS, loss of connectivity
SYS	Green	Permanently lit: system OK Permanently lit: together with SYS Red - unit is starting Flashing regularly: HW button pushed on the unit running; factory defaults in progress; Firmware writing in progress. DO NOT POWER OFF !!
	Red	Permanently lit: together with SYS Green - unit is starting; serious system error Flashing regularly: HW button just pressed Flashing intermittently: unit in the service Linux
ETH	Green	ETH1 port Flashing regularly: Auto Negotiation in progress Flashing irregularly: Link Activity 10/100/1000 Permanently lit: Link 10/100/1000
	Orange	ETH2 port Flashing regularly: Auto Negotiation in progress Flashing irregularly: Link Activity 10/100/1000 Permanently lit: Link 10/100/1000

Flashing regularly 500 ms on / 500 ms off
Flashing intermittently 50 ms on / 950 ms off
Flashing irregularly by passing frames

3.5. Technical parameters

Basic technical parameters are stated in chapter **Technical parameters**.

3.6. Dimensions

Communication unit ODU

Outer size
- 244 x 244 x 157 mm

Weight
- RAy2-10 — 2.8 kg
- RAy2-11 — 2.8 kg
- RAy2-17 — 2.5 kg
- RAy2-24 — 2.5 kg

Diameters of supplied antennas

RAy2 units are ready for direct mounting to Jirous[1] Class 2 antennas.
Individual datasheets are accessible here[2].

Tab. 3.2: Overview of antennas

10, 11 GHz		**17 GHz**		**24 GHz**	
diameter	gain	diameter	gain	diameter	gain
38 cm	29.0 dBi	40 cm	34.8 dBi	40 cm	36.8 dBi
65 cm	35.5 dBi	68 cm	38.6 dBi	68 cm	41.7 dBi
90 cm	37.5 dBi	90 cm	41.0 dBi	90 cm	44.0 dBi
120 cm	41.0 dBi	120 cm	43.7 dBi	120 cm	46.6 dBi

Andrew (Class 2 or 3) or Arkivator antennas can also be used but require an antenna mounting kit. Flexible waveguide is a general-purpose option for any antenna usage.

Name plate

The plate contains name, bar code record, CE label, etc.:

- Type – RAy2 product line identification
- Code – detailed identification of the unit type (for details see Section 3.7, “Ordering codes”)
- S/N – serial number, MW link consists of two separated units with two different serial numbers
- QR code - www link to the latest version of the User manual
- Power DC supply connector polarity marks

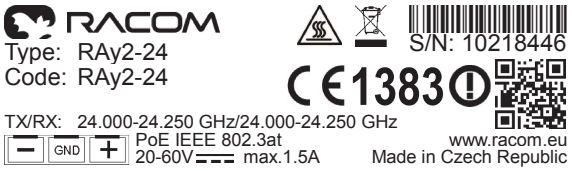


Fig. 3.9: Name plate

[1] http://en.jirous.com/
[2] http://www.racom.eu/eng/products/microwave-link.html#accessories_jirous

3.7. Ordering codes

The proper pair (from the same row) of **Lower and Upper units** should be selected when ordering the microwave link. This is not valid for RAy2-17 and RAy2-24 units. In such a case the same unit is used for both sides of the link.

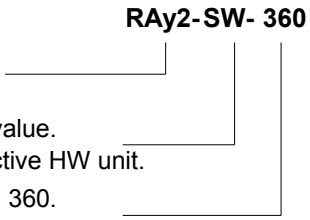
Tab. 3.3: Ordering codes

Type	Frequency		Ordering code	
	Lower [GHz]	Upper [GHz]	Lower unit	Upper unit
10 GHz	10.30 – 10.42	10.47 – 10.59	**RAy2-10-LA**	**RAy2-10-UA**
	10.125 – 10.325	10.475 – 10.675	**RAy2-10-LB**	**RAy2-10-UB**
11 GHz	10.695 – 10.970	11.185 – 11.460	**RAy2-11-LA**	**RAy2-11-UA**
	10.935 – 11.195	11.425 – 11.695	**RAy2-11-LB**	**RAy2-11-UB**
17 GHz	17.100 – 17.300		**RAy2-17**	
18 GHz [1)]	17.700 – 18.209	18.710 – 19.219	**RAy2-18-LA**	**RAy2-18-UA**
	18.167 – 18.690	19.177 – 19.700	**RAy2-18-LB**	**RAy2-18-UB**
24 GHz	24.000 – 24.250		**RAy2-24**	

ver 5.0

1) RAy2-18 not available yet

The **Feature keys** ordering code consists of three parts:



SW key possibilities, valid for RAy2-10, 11, 17, 18, 24:

- **RAy2-SW-200** User data speed up to 200 Mbps
- **RAy2-SW-360** User data speed up to 360 Mbps
- **RAy2-SW-200-360** User data speed upgrade from 200 to 360 Mbps

4. Accessories

4.1. Overview

RACOM-PART-NUMBER	Short description
Antenna Jirous	
ANT-JRMA-380-10/11R	Antenna parabolic 0.38 m 10-11GHz with holder 28.0-29.0 dBi Class 2
ANT-JRMA-650-10/11R	Antenna parabolic 0.65 m 10-11GHz with holder 34.1-35.5 dBi Class 2
ANT-JRMB-900-10/11R	Antenna parabolic 0.9 m 10-11GHz with holder 37.0-37.5 dBi Class 2
ANT-JRMB-1200-10/11R	Antenna parabolic 1.2 m 10-11GHz with holder 40.0-41.0 dBi Class 2
ANT-JRMB-400-17R	Antenna parabolic 0.4 m 17 GHz with holder 34.8 dBi Class 2
ANT-JRMB-680-17R	Antenna parabolic 0.68 m 17 GHz with holder 38.6 dBi Class 2
ANT-JRMB-900-17R	Antenna parabolic 0.9 m 17 GHz with holder 41.0 dBi Class 2
ANT-JRMB-1200-17R	Antenna parabolic 1.2 m 17 GHz with holder 44.6 dBi Class 2
ANT-JRMB-400-24R	Antenna parabolic 0.4 m 24 GHz with holder 36.8 dBi Class 2
ANT-JRMB-680-24R	Antenna parabolic 0.68 m 24 GHz with holder 41.7 dBi Class 2
ANT-JRMB-900-24R	Antenna parabolic 0.9 m 24 GHz with holder 44.0 dBi Class 2
ANT-JRMB-1200-24R	Antenna parabolic 1.2 m 24 GHz with holder 46.6 dBi Class 2
Antenna mounting kit	
SET-RAY10-ANW	Set mouting RAy10/11 Antenna Andrew 60, 100
SET-RAY10-ARK	Set mouting RAy10/11 Antenna Arkivator 30, 60, 99, 120
SET-RAY17-ANW	Set mouting RAy17 Antenna Andrew 30, 60, 100
SET-RAY17-ARK	Set mouting RAy17 Antenna Arkivator 30, 60, 99
SET-RAY24-ANW	Set mouting RAy24 Antenna Andrew 30, 60, 100
SET-RAY24-ARK	Set mouting RAy24 Antenna Arkivator 30, 60, 99, 120
Flexible waveguide mounting kit	
SET-RAY-FX-R100	Set mouting RAy2 to flange R100
SET-RAY-FX-R120	Set mouting RAy2 to flange R120
Cable bushing	
SET-RAY2-CON-B	Basic set cable bushings and connectors
SET-RAY2-EXT35	Cable bushing lengthening, PG21, 35 mm
SET-RAY2-EXT-F50	Cable bushing lengthening, PG21, Flexi, 50cm
Power supply DC	
PWS-AC/DC-AD-55B	Power supply 90-260 VAC / 50 W at 27.6 VDC MeanWell
Power supply PoE	
PWR-POE36U-1AT	Power supply PoE 1xGb Eth 90-264 VAC/ 33.6 W at 56 VDC Phihong
PWR-POE36D-1AT	Power supply PoE 1xGb Eth 36-72 VDC/ 33.6 W at 56 VDC Phihong
Power supply PoE 4x Eth	
PWR-POE125U-4AT-N	Power supply PoE 4xEth 90-264 VAC/ 33.6 W/Port 0/+40°C Phihong
Power supply holder	

HOL-POE-PHI-1A	DIN rail holder for PoE Phihong
HOL-POE-PHI-4A	19" Rack holder for 1xPOE125U-4-AT-N Phihong
Surge protection	
OTH-DL-1GRJ45	Surge protection 1Gb Eth Cat.6 LPZ0B-LPZ1 IP20 -40/+85°C
OTH-DL-CAT.6-60V	Surge protection 1Gb Eth Cat.6 LPZ2-LPZ3 IP20 -40/+85°C
CAT5e, CAT7 cable	
CAB-CAT5E-FTP-TLD	Double shell outdoor FTP Cat5e cable TELDOR
CAB-S/FTP 4x	Double shell outdoor FTP Cat7 cable PEWTRONIC
CAT6 connector	
CON-RJ45-UBNT-CAT6	Connector TC-CON, STP RJ45, Cat6, 8p8c, wire, pleated, AWG24, UBNT
SET-RAY2-TLG-EXT35	Set RJ45 connector (Telegärtner) and cable bushing lengthening (35mm)
SFP module RJ45	
SFP-RJ45-AVAGO	SFP module, RJ45 interface, -40°C to +85°C , Avago
SFP module optical	
SFP-DLC-APAC	SFP module, 2-fibres, LC, 10km, -40°C to +85°C, APAC Opto
Fibre cable patchcord/pigtail	
CAB-FIB-2F-DLC/DLC-OFA-5m	Fibre patch cord, 2-fibres, single mode, LC-connector — LC-connector, OFA, 5 m
CAB-FIB-1F-LC/LC-OFA-5m	Fibre patch cord, 1-fibre, single mode, LC-connector — LC-connector, OFA, 5 m
CAB-FIB-2F-DLC/x-OFA-5m	Fibre pigtail, 2-fibres, single mode, LC-connector — loose end, OFA, 5 m
CAB-FIB-1F-LC/x-OFA-5m	Fibre pigtail, 1-fibre, single mode, LC-connector — loose end, OFA, 5 m
DC & Fibre cable patchcord	
CAB-HYB-2F-DLC/DLC-OFA-030m	DC power cable - Fibre: patchcord, 2-fibres
DC cable	
CAB-DC-2x1.5	DC power cable 2x1.5 mm, silicone rubber
DC surge protection	
OTH-DP-024	Overvoltage protection, DC 24V, LPZ1-LPZ2, IP20, -40/+85°C , Saltek
RAy grounding kit	
KIT-GROUDING-1/4"	Grounding kit for antenna cable
KIT-GROUDING-RAY	Grounding kit for mast grounding
Access adapters	
OTH-W1-WIFI	Wifi adapter
SET-X5-ETH/USB	Ethernet adapter

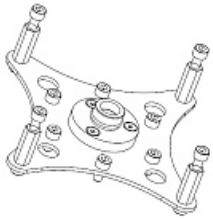
4.2. Details

Antenna

The overview of different Jirous antenna types is listed in Section 3.6, “Dimensions”. The antenna choice determines radio link properties. The radio link calculation should be performed to determine proper antenna size. Rough calculation can be done using a simple on-line calculator.[1]

- see the Overview
- List of datasheets[2]

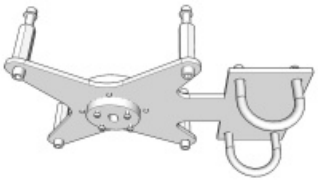
Antenna mounting kit



Other manufacturer's antennas can also be used with RAy2 links. The RAy2 unit can be attached by means of special interconnetions. There are several types of these parts for Andrew and Arkivator antennas. It is also possible to develop interconnetions for other antenna types.

- see the Overview
- The bracket for mounting FOD unit on the antenna.

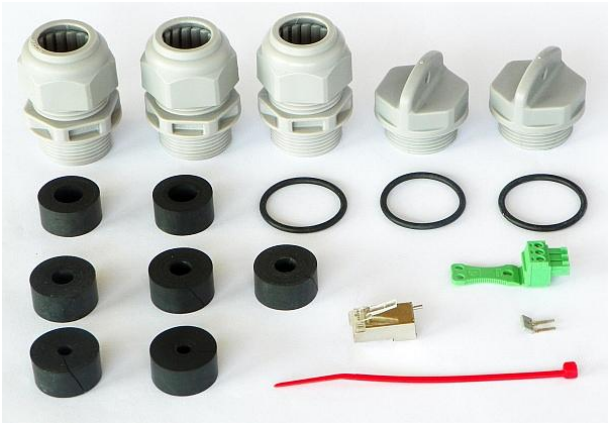
Flexible waveguide mounting kit



The RAy2 unit can be attached to the antenna by flexible waveguide.

- **SET-RAY-FX-R100**
- **SET-RAY-FX-R120**
- The bracket for mounting the flexible waveguide on the FOD unit.

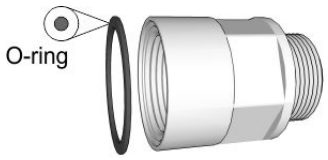
Cable bushing



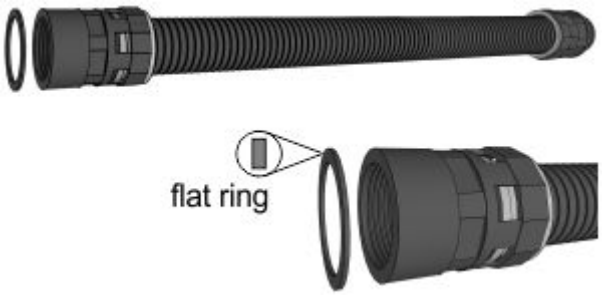
- **SET-RAY2-CON-B**
- Basic set cable bushings and connectors contains:
  - 3 pc standard PG21 bushing with nut
  - 2 pc blind plug Racom
  - 3 pc O-ring
  - 2 pc rubber sealing small diameter
  - 3 pc rubber sealing medium diameter
  - 2 pc rubber sealing big diameter
  - 1 pc DC connector
  - 1 pc tie wrap
  - 1 pc connector jumper
  - 1 pc RJ-45 ethernet connector

[1] http://www.racom.eu/eng/products/microwave-link.html#calculation
[2] http://www.racom.eu/eng/products/microwave-link.html#accessories

- **SET-RAY2-EXT35**
- Cable bushing lengthening, PG21, 35 mm
- O-ring



- **SET-RAY2-EXT-F50**
- Cable bushing lengthening, PG21, Flexi, 50cm
- orig. part no: LPA6-23N-0.5m, RKG-23P21N, RKF-23P21N, 2xORC-23, flat ring FSN-P21



Power supply DC

- **PWS-AC/DC-AD-55B**
- orig. part no: AD-55B
- FOD unit power supply 50 W, 24 V, UPS Function, MeanWell
- Datasheet[3]

Power supply PoE

- **PWR-POE36U-1AT**
- orig. part no: POE36U-1AT
- FOD unit power supplies – 30 W PoE adapters, 1x Eth
- Input 100 to 240 VAC, Output 56 V / 33.6 W, Phihong
- Datasheet AC[4]

- **PWR-POE36D-1AT**
- orig. part no: POE36D-1AT
- Input 36 to 72 VDC / 1.2 A, Output 56 V / 33.6 W, Phihong
- Datasheet DC[5]

Power supply PoE 4x Eth

- **PWR-POE125U-4AT-N**
- orig. part no: POE125U-4AT-(x)
- FOD unit power supply 4x 33 W, 4x Eth, Phihong
- Datasheet[6]

[3] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/PWS-AC-DC-AD-55B.pdf
[4] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/PWR-POE36U-1AT.pdf
[5] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/PWR-POE36D-1AT.pdf
[6] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/PWR-POE125U-4AT-N.pdf

Power supply holder

- **HOL-POE-PHI-1A**
- 1x Eth PoE power supply, DIN rail mountable

- **HOL-POE-PHI-4A**
- 4x Eth PoE power supply, 19" Rack mountable

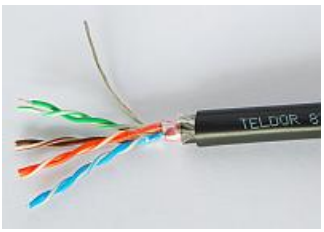
Surge protection

- **OTH-DL-1GRJ45**
- orig. part no: DL-1GRJ45
- Protection from the voltage spikes
- Datasheet[7]

- **OTH-DL-CAT.6-60V**
- orig. part no: DL-Cat. 6-60 V
- Datasheet[8]

CAT5e cable

- **CAB-CAT5E-FTP-TLD**
- orig. part no: PLU030078
- Cat.5e cable for connecting FOD units to the network, TELDOR
- Datasheet[9]

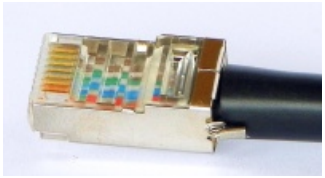


CAT7 cable

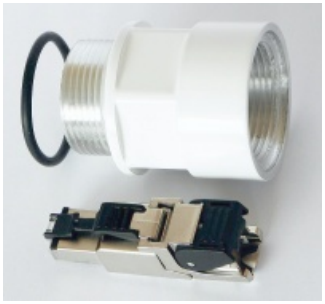
- **CAB-S/FTP 4x**
- orig. part no: S / FTP 4x (2x23AWG) Cat.7 + 2x (2×24 AWG)
- Cat.7 cable for connecting FOD units to the network, PEWTRONIC Ltd.
- Datasheet[10]

[7] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/OTH-DL-1GRJ45.pdf
[8] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/OTH-DL-CAT-6-60V.pdf
[9] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/CAB-CAT5E-FTP-TLD.pdf
[10] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/CAB-SFTP-4x.pdf

CAT6 connector



- **CON-RJ45-UBNT-CAT6**
- orig. part no: TC-CON connector STP RJ45
  STP RJ45 /Cat6 / 8p8c / wire/ gold plated/ AWG24, UBNT



- **SET-RAY2-TLG-EXT35**
- orig. part no: Telegärtner MFP8 Cat.6A AWG 22-27
  Connector RJ45, Cat6A, AWG 24-22, Telegärtner
  + Racom SET-RAY2-EXT35
- Set RJ45 connector (Telegärtner) and cable bushing lengthening (35mm). Suitable for AWG24-22 (Cat5e, Cat6A, Cat7) cables.
- Datasheet[11]

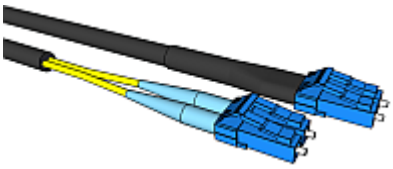
SFP module RJ45

- **SFP-RJ45-AVAGO**
- orig. part no: ABCU-5730ARZ
  SFP module, RJ45 interface, -40°C to +85°C , Avago
- Datasheet[12]

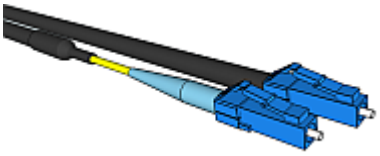
SFP module optical

- **SFP-DLC-APAC**
- orig. part no: LS38-C3S-TI-N-DD
  SFP module, 2-fibres, LC, 10km, -40°C to +85°C, APAC Opto
- Datasheet[13]

Fibre cable - outdoor patchcord / outdoor pigtail



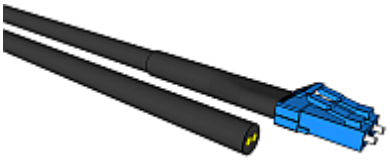
- **CAB-FIB-2F-DLC/DLC-OFA-5m**
- orig. part no: DLCRAC2Fyyy
  patchcord, 2-fibres, single mode, LC-connector — LC-connector, yyy meters, OFA



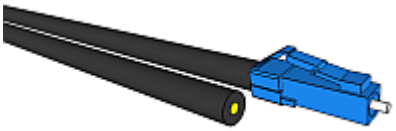
- **CAB-FIB-1F-LC/LC-OFA-5m**
- orig. part no: LCRAC1Fyyy
  patchcord, 1-fibre, single mode, LC-connector — LC-connector, yyy meters, OFA

[11] http://www.racom.cz/download/hw/ray/free/eng/07_prislusenstvi/SET-RAY2-TLG-EXT35.pdf
[12] http://www.racom.cz/download/hw/ray/free/eng/07_prislusenstvi/SFP-RJ45-AVAGO.pdf
[13] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/SFP-DLC-APAC.pdf

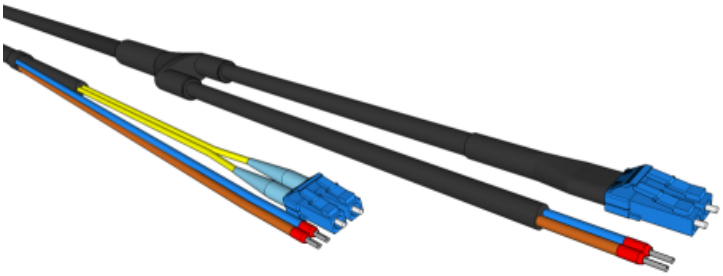
- **CAB-FIB-2F-DLC/x-OFA-5m**
- orig. part no: DLC0RAC2Fyyy
  pigtail, 2-fibres, single mode, LC-connector — loose end,
  yyy meters, OFA



- **CAB-FIB-OFA-1F-LC/x-OFA-5m**
- orig. part no: LC0RAC1Fyyy
  pigtail, 1-fibre, single mode, LC-connector — loose end,
  yyy meters, OFA
- Datasheet[14]



Fibre & DC outdoor cable



- **CAB-HYB-2F-DLC/DLC-OFA-030m (example for 30m long cable)**
- orig. part no: DLCHRAC2Fyyy Phoenix Microwave Hybrid Cable LSOH, yyy meters, OFA
  DC: 2x1.5mm^2; fibre: patchcord, 2-fibres, single mode, LC-connector — LC-connector
- Datasheet[15]

DC cable

- **CAB-DC-2x1.5**
- orig. part no: V05SS-F 2Dx1.50
  silicone rubber, 2x1.5 mm², -40 to +60°C, ProPS
- Datasheet[16]

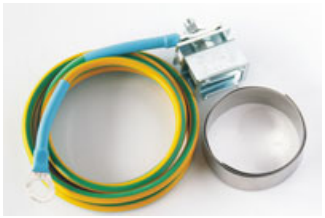
DC surge protection

- **OTH-DP-024**
- orig. part no: DC 24V
  LPZ1-LPZ2, IP20, -40/+85°C , Saltek
- Datasheet[17]

[14] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/CAB-FIB-OFA.pdf
[15] http://www.racom.cz/download/hw/ray/free/eng/07_prislusenstvi/CAB-HYB-OFA.pdf
[16] https://webservice-new.racom.eu/main/eshop.detail?i=193
[17] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/OTH-DP-024.pdf

RAy grounding kit

- **KIT-GROUDING-1/4"**
- Grounding kit for Cat.7 S/FTP 4x(2x23 AWG) cable. Pewtronic.
- Detail see Grounding.
- Datasheet[18]



- **KIT-GROUDING-RAY**
- RAy grounding set for grounding RAy equipment to the mast. Contains a ZSA16 grounding terminal, grounding tape and a cable with grounding lugs.
- Detail see Grounding.
- Datasheet[19]

Access adapters

- **OTH-W1-WIFI**
- Wifi adapter for service access to the web interface via USB connector. RAy2 provides a built-in DHCP server with up to 6 leases. To access the RAy2 always use the fixed IP 169.254.169.168 (Lower Unit) or 169.254.170.168 (Upper Unit).

- **SET-X5-ETH/USB**
- Ethernet adapter for service access to the web interface via USB connector. RAy2 provides a built-in DHCP server with up to 6 leases. To access the RAy2 always use the fixed IP 169.254.169.168 (Lower Unit) or 169.254.170.168 (Upper Unit).

Extended descriptions

See www.racom.eu, Microwave link, Accessories[20]

E-shop

Accessories easiest to order here:

E-shop RACOM[21]

Use there a search engine Ctrl+F and RACOM-PART-NUMBER of the searched item.

[18] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/KIT-GROUDING-RAY.pdf
[19] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/ZSA16-en.pdf
[20] http://www.racom.eu/eng/products/microwave-link.html#accessories
[21] https://webservice-new.racom.eu/main/eshop.list?a=1&t=10

5. Step-by-step Guide

The following chapters will guide you step by step through preparation, installation and activation of the RAy2 link:

- Pre-installation check out
- Installation (Chapter 6, *Installation*)
- Advanced configuration (Chapter 7, *Configuration*)
- Troubleshooting (Chapter 9, *Troubleshooting*)

Pre-installation Checklist

Familiarise yourself with the controls and prepare your configuration ahead of the installation of the link on the mast tube.

Both units (without antennas) can lie on a desk with flanges running parallel and facing up at an angle; on a non-metal desk they can also face downward. In the case of units RAy2-17 and RAy2-24 turn the unit holders so that they are roughly perpendicular to each other. In the case of units operating in licensed bands (RAy2-10, RAy2-11), turn unit holders so that they are roughly parallel to each other. Use an ethernet cable to connect each of the units to a PoE source and connect a PC to one of them for configuration.

Take the following steps to establish a connection between the PC and RAy2 and perform a basic setup.

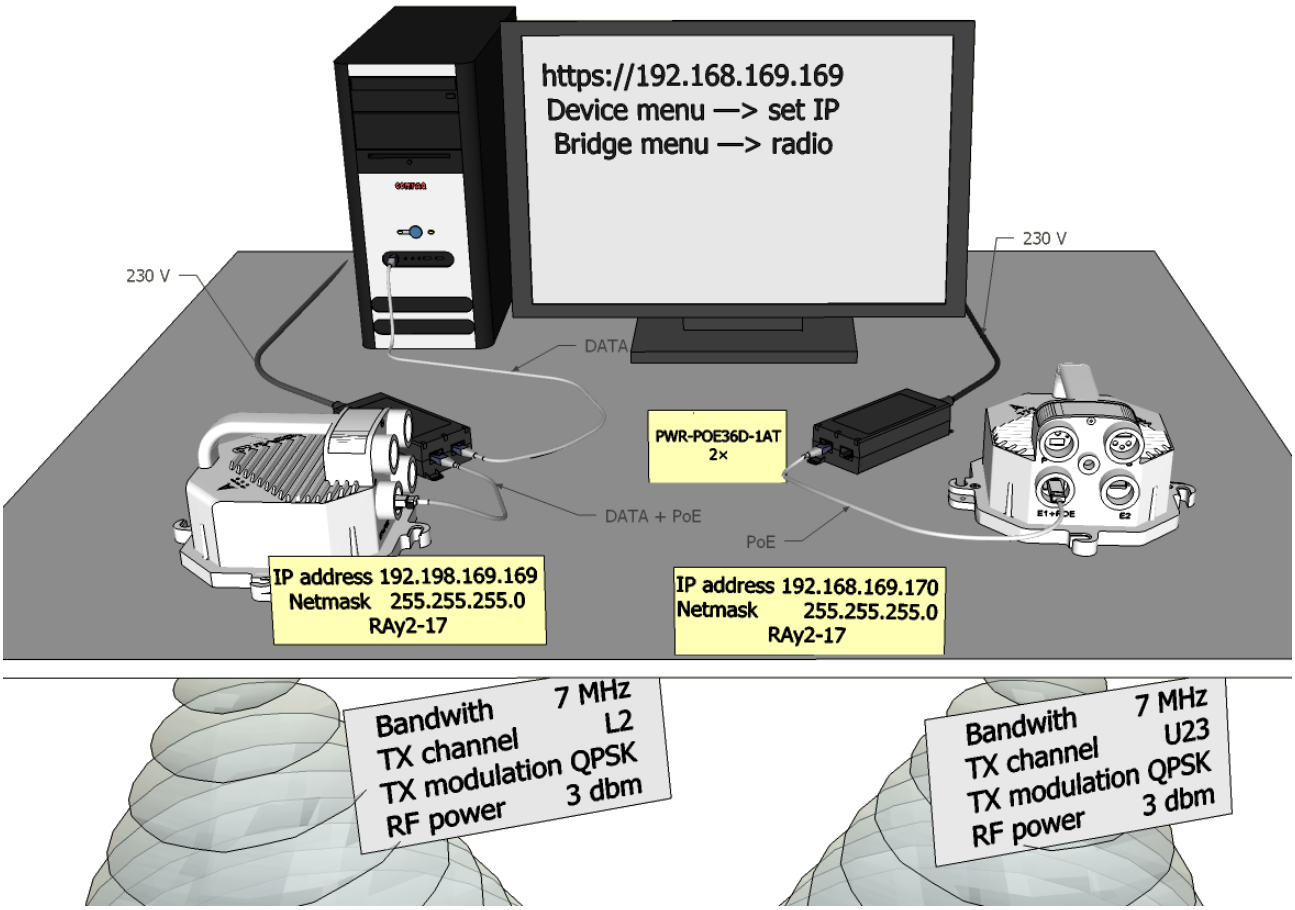


Fig. 5.1: Link Configuration (RAy2-17, perpendicular holders)

Warning

During operation, never bring the waveguides of the stations close to each other. There is a risk of damaging sensitive input circuits.

5.1. Service access

The RAy2 link is supplied with a default configuration of access parameters:

Unit L has the service IP address 192.168.169.169 and mask 255.255.255.0,
Unit U has the service IP address 192.168.169.170 and mask 255.255.255.0,
access is allowed over HTTP, HTTPS or SSH,
the username is *admin* and the password is also *admin*.

On your PC setup an IP address that is within the mask, e.g. 192.168.169.180.

Then open the https configuration interface, e.g.
https://192.168.169.169

Other access options are described in the chapter Configuration - Link settings - Service access of this manual.

When connection has been established, use the *Service access* menu to customise access parameters. Default IP addresses should be replaced with well-chosen operating addresses. Leaving default addresses in place can lead to network problems later.

The menu contains parameters for the entire link, both for the Local and remote Peer units. If a connection has been established, both sets of parameters have been set. While working with an isolated unit, only Local parameters are functional for the currently connected unit.

Note

If the link is **OK** and there are no parameters shown of the station **Peer**, it is necessary to click on **Refresh**.

Follows the description of basic settings. After entering values on the screen always save the content by clicking on **Apply**.

Note

If there is any problem with https certificate after completing the firmware upgrade, please see the Annex Https certificate for further steps.

5.1.1. Menu Link settings - General

- Station name – station can be assigned with a name, e.g. the place of installation.
- Station location – for easier inclusion the network hierarchy, it is possible to enter the station's location

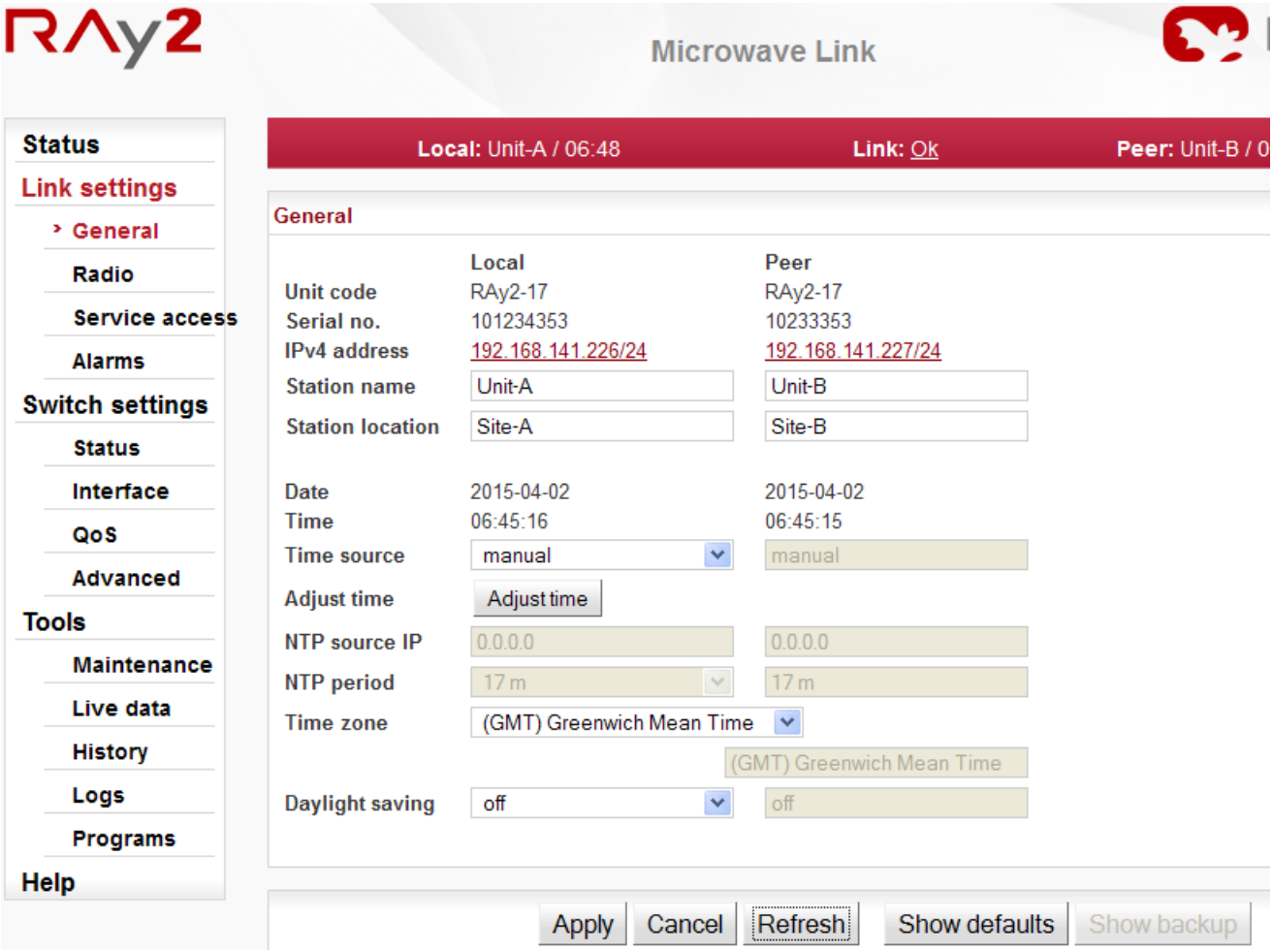


Fig. 5.2: Configuration Menu Link settings - General

5.1.2. Menu Link - Service access - Services

- IPv4 address – enter a valid IP address to access the drive. The default IP address has to be replaced with a valid address. Keeping the default address will probably lead to future problems in the network.
- Netmask – enter the network mask.
- Gateway – if necessary, enter a gateway, otherwise leave blank
- Enable access protocols that you are going to need. For security reasons, do not enable more than is necessary.
- HTTP(S) – allow access to the web interface.
- Telnet – enabling access to the CLI interface using telnet protocol.
- SSH – enabling access to the CLI interface using SSH protocol.
- Management VLAN – Enabling 802.1Q VLAN tag for separation of user and service operations.
- Management VLAN id – Defining 802.1Q VLAN tag for service operations.

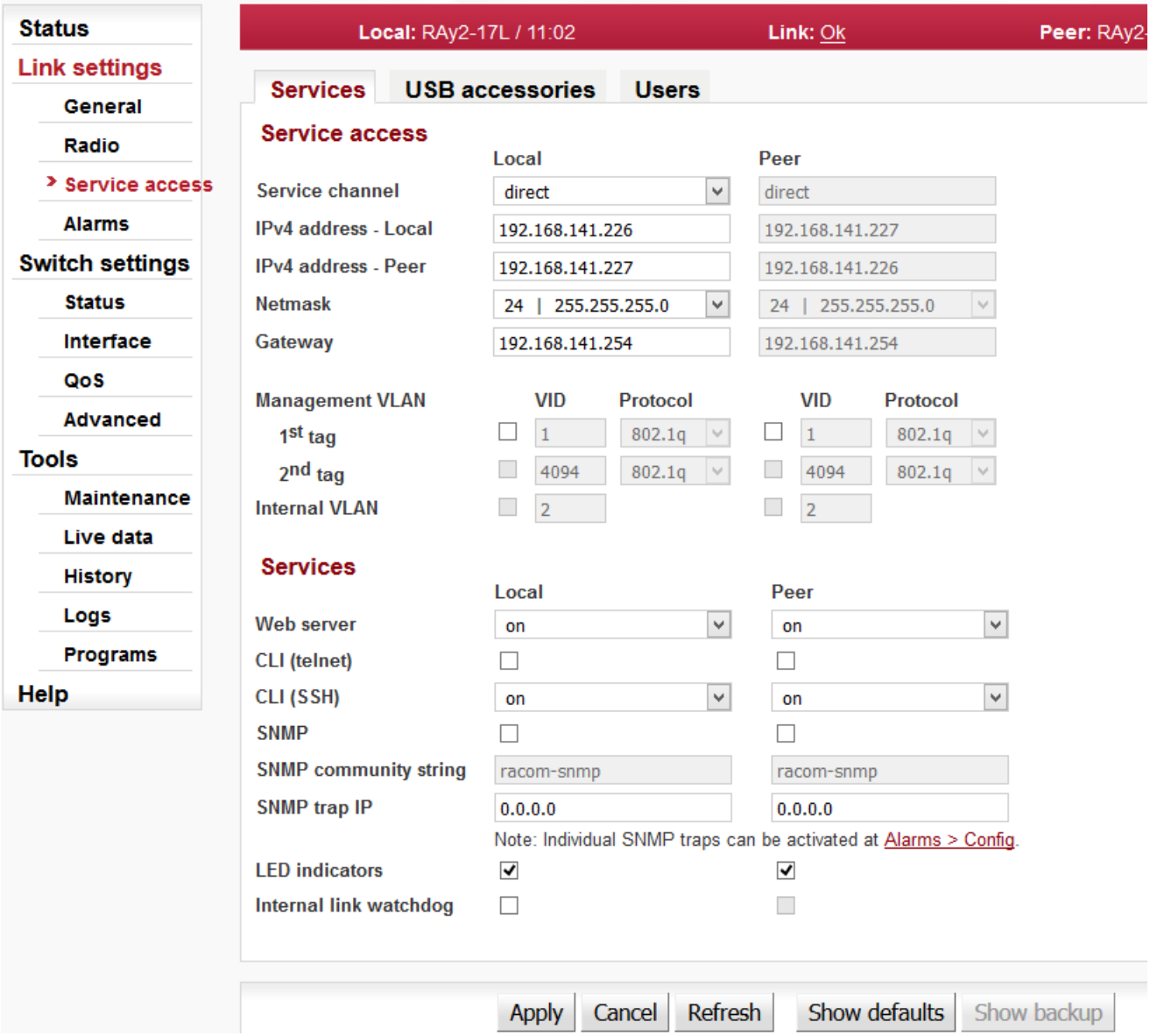


Fig. 5.3: Configuration menu Link settings – Service access – Services

5.1.3. Menu Link - Service access - Users

- *Edit* - enter the menu.
- *New password* – choose a password and enter it.
- *Confirm password* – enter the password again to confirm.

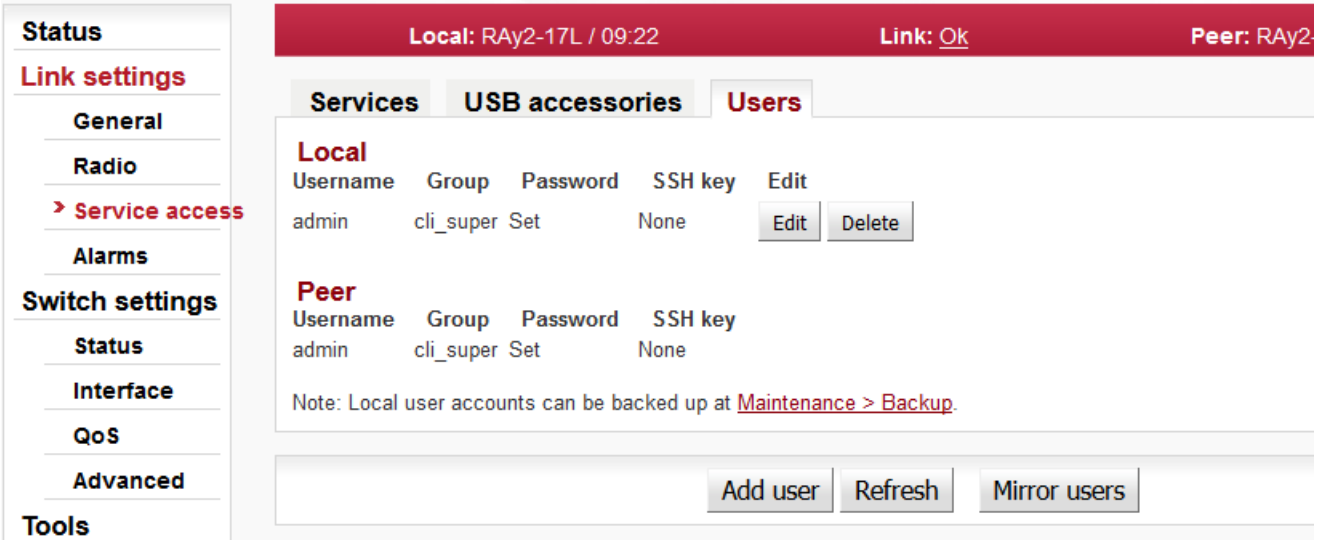


Fig. 5.4: Configuration menu Link settings – Service access – Services

5.1.4. Menu Maintenance - Feature keys

The firmware of the microwave link is capable of controlling the maximum user data speed. The default user speed without the feature key is the minimum for the respective hardware unit. The feature key to assign the maximum user data speed, should be installed prior to physical installation. For further details see the section called “Feature keys”.

5.2. Basic link configuration

Default radio parameters depend on the specific type of link and the specific channel allocation table. Channels are typically set in the lower part of the band, the smallest bandwidth, QPSK modulation, and low power. Both units in the pair should be capable of immediate communication. If it is possible to work with these radio parameters at the installation location, the link can be activated. On an operating link the required operating parameters can then be set up.

If a change in the parameters is necessary, it is done in the menu *Link settings – Radio* and saved by clicking Apply. This applies when working on both units simultaneously if they are connected, otherwise each unit is configured individually. When configuring units individually, pay attention to correct settings of duplex pair for channels TX and RX. For example, if one station has TX channel L1, then the second station must also have the channel RX L1.

5.3. Link test

Verify the functionality of the radio link:

- Switch in screen *Status - Brief.*
- Status Bar displays *Link: Ok*.

If the alarm message appears at Local or Peer, this doesn't necessarily mean there is a problem. The message indicates that the limit at any of the monitored parameters has been exceeded. Essential is the *Link: Ok* message on the status bar.
- The *Status* screen contains values for both Local and Peer units. N/A next to Peer indicates that the data from the Peer unit has not been transferred. If *Link* is *Ok*, simply click Refresh at the bottom of the screen and Peer data will be updated.
- Menu *Status – Detailed – Radio* indicates link RSS and SNR values, in case of ACM also the selected modulation and Netbitrate. If the ATPC function is enabled (menu *Link settings – Radio*) it also indicates instantaneous / max. allowed power and for SNR and RSS values it indicates immediate / target value size.
- Menu *Tools – Live data – Bar indicators* displays current size of RSS, SNR and BER.
- Menu *Tools – Ping* allows you to send a ping test to the selected IP address.

Try out the possibility of modulation:

- Modulation ACM. In menu *Link settings – Radio* enable ACM. Set the TX modulation parameter to the required maximum value. In menu *Status – Brief – Radio* you can monitor (Refresh or Start) changes in used modulation based on the instantaneous SNR signal quality. The status and quality of modulation is demonstrated well in menu *Tools – Live data – RX constellation diagram*, hit Refresh.
- To set a fixed modulation go to *Link settings - Radio*, switch off ACM and set the TX modulation to a value from the range of QPSK through 256-QAM based on the results of the previous test. If you choose modulation higher than allowed by SNR, the connection will be lost. *Status Link* will lose its *Ok* value. Both units will need to be moved closer to resume the link. If this is not possible, use the ethernet to access each unit individually and set the basic modulation QPSK. You can monitor the quality of the received signal under *Tools – Live data – RX constellation diagram*.

Verify the functionality of the entire link:

- If possible, connect user devices to both RAy2 units over PoE and test mutual communication.
- Another way of testing this is to connect a PC to the other unit and send a ping from one PC to the other.
- The minimum variant of this test is to use an ethernet cable connection from the PC connected to the local RAy2 to the PC connected to the remote RAy2 and test communication between both units over ethernet. This will verify ethernet functionality.

Prepare installation configuration:

- Bandwidth e.g. 3.5 MHz. To get the highest possible receiver sensitivity, set the bandwidth as narrow as possible according to specific frequency band.
- TX channel: Use your allocated channel. If you don't have allocated channel yet, use for example channel L1.
- RX channel will setup automatically when channel lock activates.
- Set TX modulation QPSK to get the highest possible sensitivity.
- Set RF power according to selected antenna and according to individual frequency licence. Set the output power as high as possible.
- Set a new users access passwords.
- Record the access parameters from the Service access menu, especially the IP addresses.
- Restart by interrupting the power supply to verify that the parameters are stored correctly and the link works.

After this preparation phase you can continue to install your devices in a working environment.

6. Installation

6.1. Line of sight test

Before you install the device to a mast tube, verify visually that the view in the direction of the remote unit is unobstructed.

Line of sight considerations:

- Free Fresnel zones. Signal needs space wider than the diameter of the antenna.
- Trees at the lower end of the Fresnel zone. They will be taller in a few years.
- Possible building development.
- Objects in the close proximity of the antenna such as edges of other antennas, their mounting racks, edges of the roof.

6.2. Antenna mounting

6.2.1. Mounting methods

- Mounting on the mast tube can be achieved by:
  - right-side mounting or
  - left-side mounting
- Mounting the FOD unit for antenna polarization can be achieved using:
  - horizontal RX polarization mounting or
  - vertical RX polarization mounting

In both cases mount the unit with the connectors facing downwards at an angle.

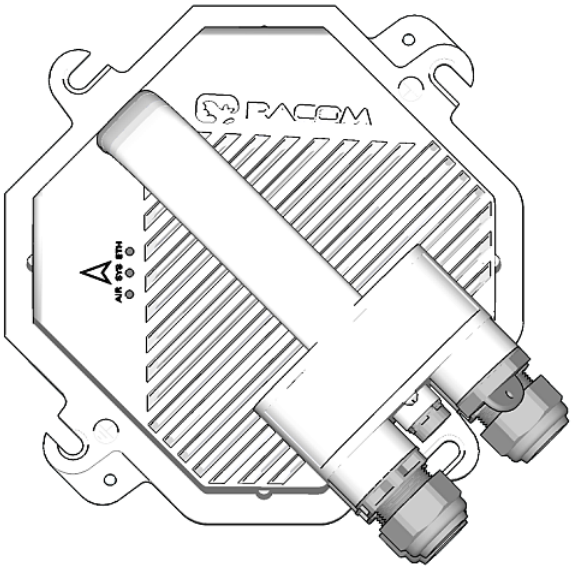


Fig. 6.1: Horizontal RX polarization – see the arrow sign

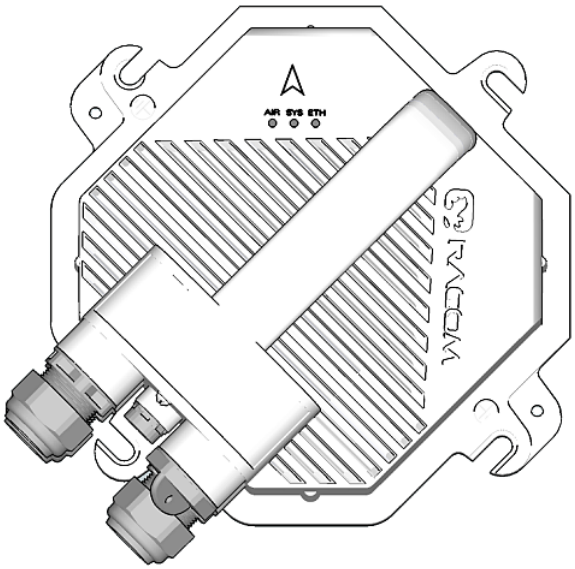


Fig. 6.2: Vertical RX polarization – see the arrow sign

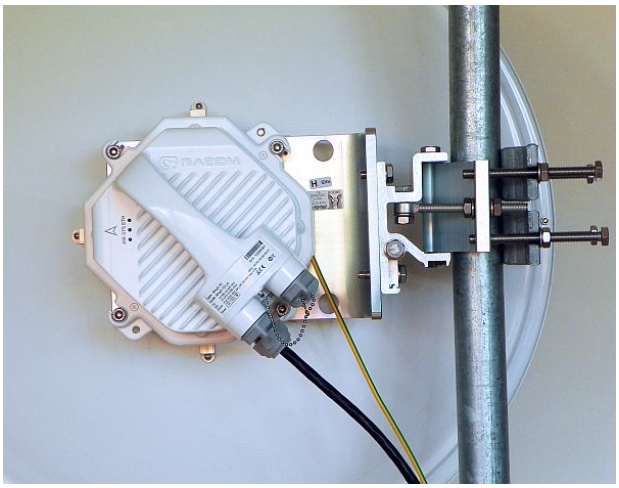


Fig. 6.3: Left-side mounting – horizontal RX polarization

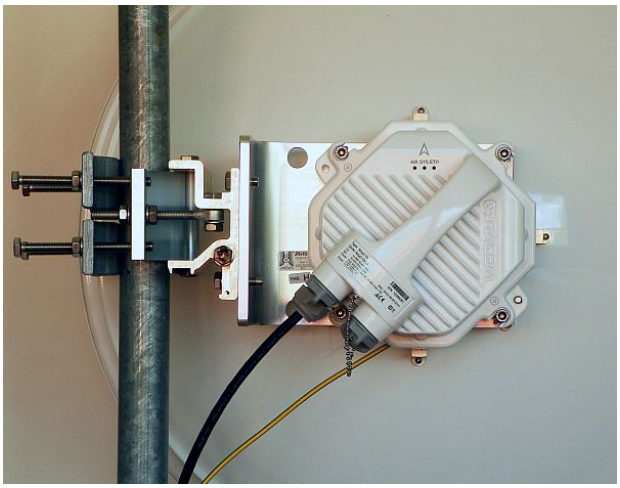


Fig. 6.4: Right-side mounting – vertical RX polarization

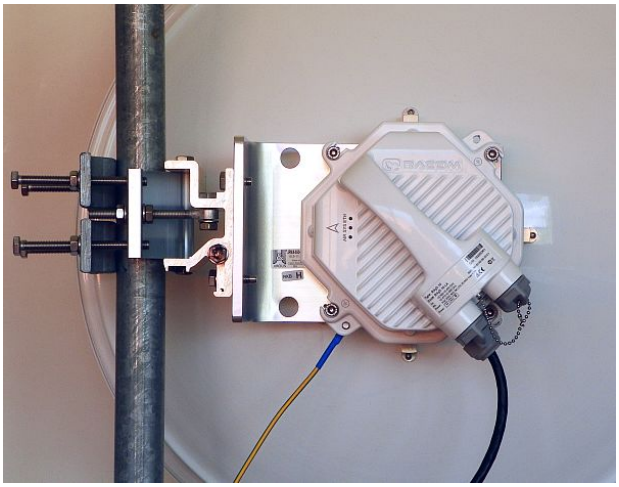


Fig. 6.5: Right-side mounting – horizontal RX polarization

Changing the mounting method

An antenna bracket is supplied as standard partly assembled, and ready for right-side mounting.

On changing the Jirous antenna bracket for left-side mounting the adjustment bolt (part No. 11) and swivel bolt (part No. 6) need to be unscrewed, then shift the bracket body (part No.5) to the other side of clamp plate (part No. 4), (do not turn upside down) and then insert bolt (part No. 6) into the second hole on the mounting plate holder and through the same hole on the clamp plate and secure in place with the nuts. The adjustment bolt (item No. 11) and nuts are switched to the other side of the clamp plate (part No. 4). It is also necessary to switch the hanging bolt (part No. 7) on the antenna mounting plate to the second hole so that after switching sides with the antenna it is on the top again.

In the case of the antenna when changing the method of mounting from right-side to left-side it is only necessary to rotate the plastic cover of the antenna. This is not only important from an aesthetic point of view, so that the RACOM logo is not upside down, but also because there is a discharge channel on the lower edge of the dish (except for ø380 mm dishes).

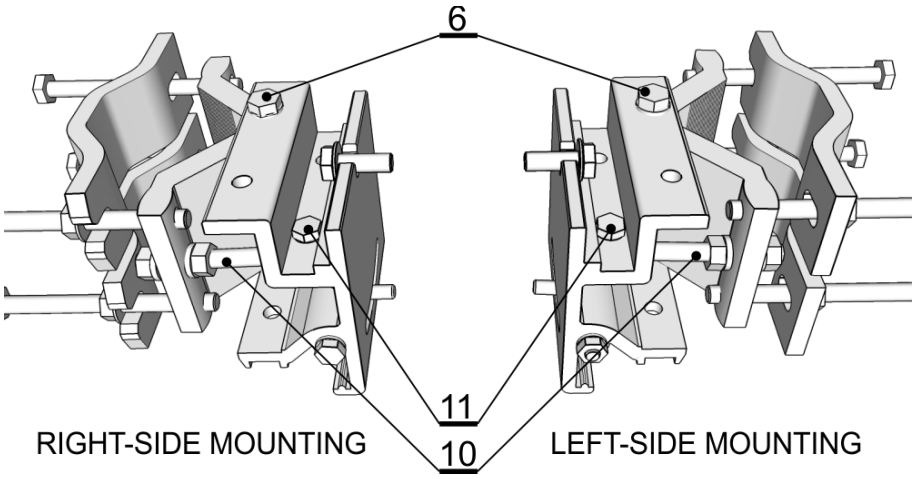


Fig. 6.6: Changing the mounting method

When changing the polarization from horizontal to vertical only the FOD unit needs to be turned through 90° around the central antenna pin by unscrewing the four bolts on the dish using a No. 6 Allen key.

Important

The RAy2-17 and RAy2-24 links are equipped with a polarization duplexer and work in both polarizations simultaneously, see **Cross polarization**. One side of the link must therefore be installed in vertical polarization and the other in the horizontal polarization.

6.2.2. Mounting the FOD unit on the antenna

RAy2 microwave bridge equipment is generally supplied as several component parts packaged separately in a box.

- Two parabolic antennas with assembled mounting plates. There are also 4 screws in a small plastic bag in the box.
- Two brackets for mounting the antenna to the mast.
- Two FOD stations, each separate in a box, in a single package.
- Other accessories based on the order placed (for more detailed information see chapter Chapter 4, *Accessories*)

A No. 17 spanner and a No. 6 Allen key are required for mounting the mechanical parts of the antenna. Spanner No. 17 serves for precisely setting the direction of the antenna. Both spanner and key can be found in the **RAy Tool** set for installing RAy2 microwave bridges.
It is advisable to lightly **lubricate** the retaining screws eg. by the supplied grease.

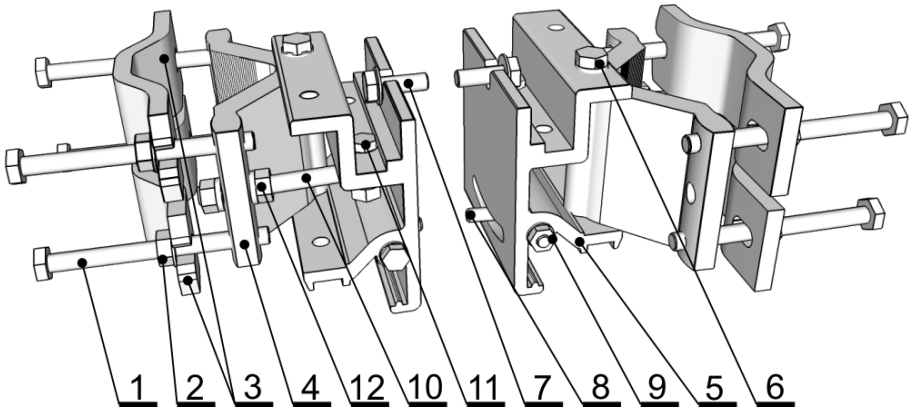


Fig. 6.7: Close up image of the mounted bracket showing numbered parts

a. Prepare the antenna bracket based on the diameter of the mast tube. For smaller diameters face the bent part of the saddle plate (part No. 3) inwards. For larger diameters it should face outwards. Screw the bolts (part No. 1) into the clamp plate (part No. 4) so that they protrude approx. 1 cm through the clamp plate. Clamp the saddle plate to the mast by tightening the nuts (part No. 2) on the bolts.

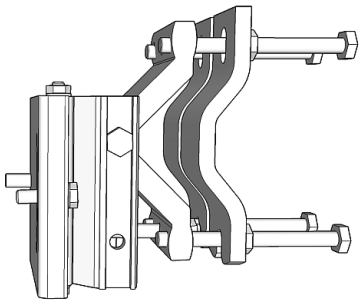


Fig. 6.8: Position of the saddle plate for ø 40–80 mm

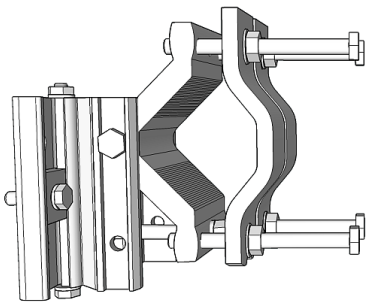


Fig. 6.9: Position of the saddle plate for ø 65–115 mm

b. Slide the antenna bracket onto the mast tube and clamp to the mast by tightening the nuts. Recommendation: Keep the gap between the two saddle plates (part No. 3) as wide as possible, so the horizontal angle adjustement screw can fit in this gap. The range of horizontal adjustement is consequently wider. This has a bigger effect when the mast diameter is smaller.

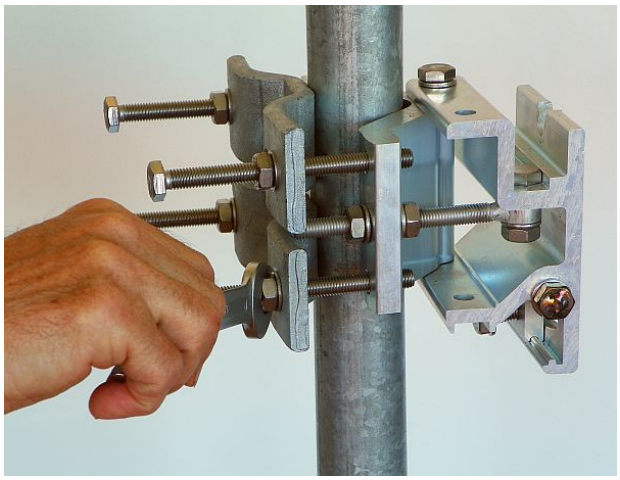


Fig. 6.10: Attaching the bracket to the mast tube

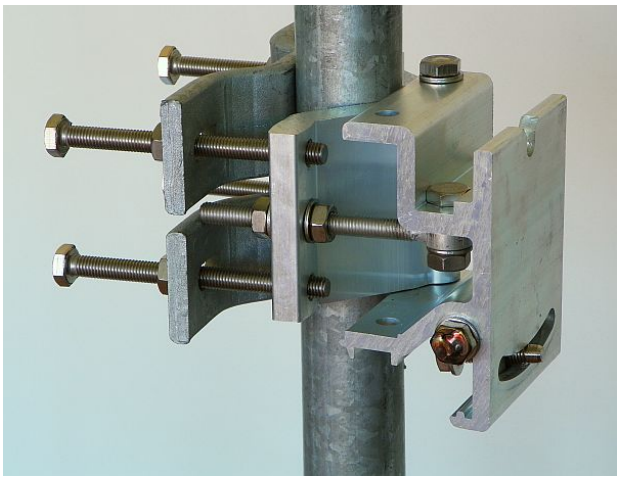


Fig. 6.11: Bracket on the mast tube

c. Screw the hanging bolt (part No. 7) into the upper hole of the mounting plate so that the antenna can be hung on the mounting plate holder. Hang the antenna on it and tighten the lower bolt. (part No. 8)

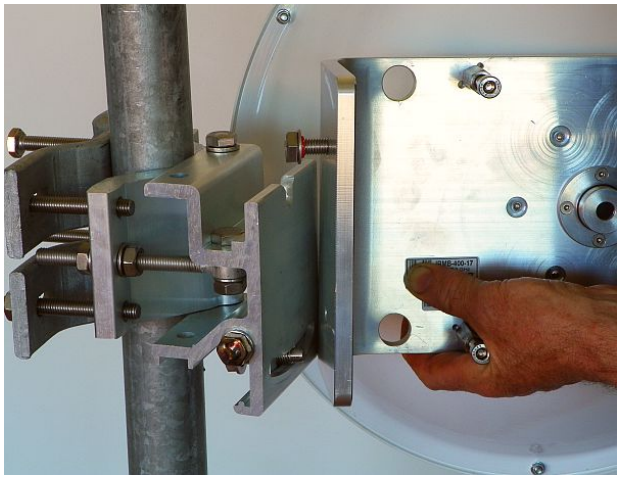


Fig. 6.12: Hanging the bolt on the holder

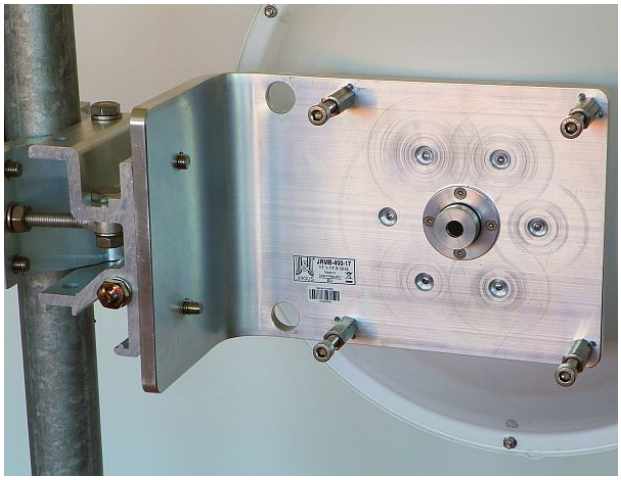


Fig. 6.13: Correct position of the mounting plate

d. Tighten both bolts to the plate before continuing with installation to prevent any unnecessary movements of the equipment. Before precisely adjusting the vertical direction of the antenna upon completing installation it will be necessary to unscrew them again as the lower bolt (part No. 8) passes through the adjustment block and the upper one (part No. 7) serves as the axis of rotation.

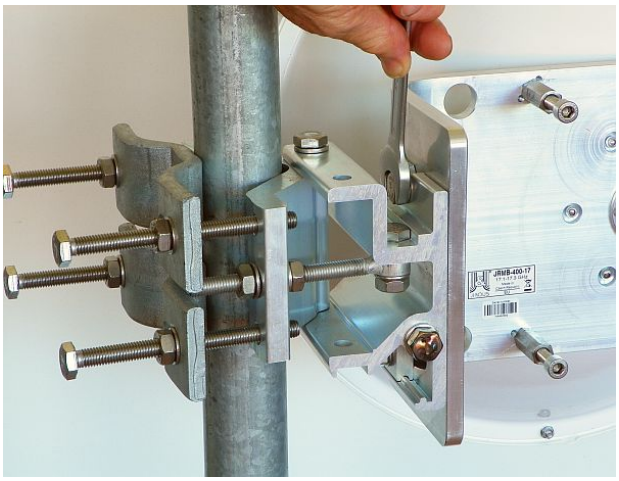


Fig. 6.14: Tightening the upper bolt to the mounting plate

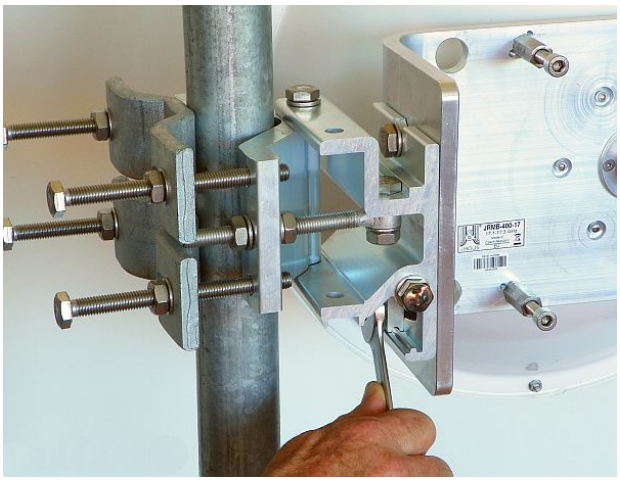


Fig. 6.15: Tightening the lower bolt to the mounting plate

e. Before installing the FOD unit on the antenna first unscrew the 4 bolts on the back of the antenna enough so that the unit can be slid on to them. Then check whether the "O" ring is correctly fitted on the antenna pin, and make sure it is not damaged and has been lubricated with grease – see Section 6.2.3, “Lubrication and preservation of the antenna pivot”. Then remove the protective plastic cover from the central pin of the antenna and fit the FOD unit to it carefully so as not to damage the "O" ring. Secure it in place with the four bolts. Carefully ensure the correct polarization of the antenna – see Section 6.2.1, “Mounting methods”. Finally tighten the bolts with a No. 6 Allen key.

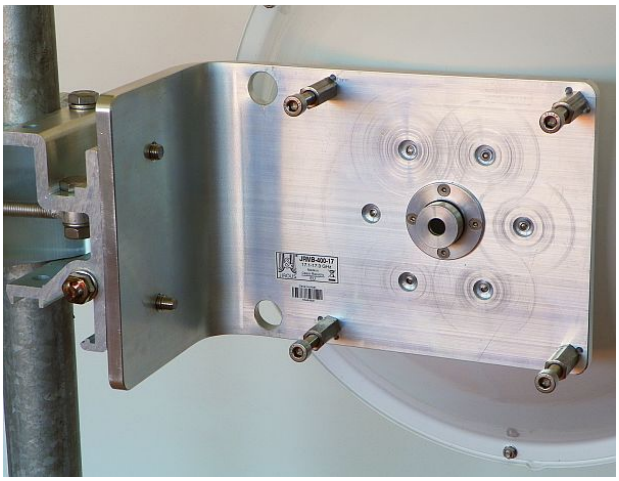


Fig. 6.16: Dish before installing the FOD unit

Fig. 6.17: Tightening bolts on the FOD unit

f. The precise horizontal direction the antenna is pointing in can be adjusted using the bolt with two nuts (part No. 10 and 12). Once the direction has been set the antenna is fixed in place by tightening the nuts against the bracket to prevent further movement of the antenna. The vertical direction the antenna is pointing in can be adjusted by turning the fine adjustment bolt (part No. 9) by the bracket mounting plate. After selecting the correct direction the position is secured by tightening the bolt – see point d. (part No. 7 and 8). The correct position in both directions is found by monitoring RSS voltage, see Section 6.5.2, “Directing antennas”.

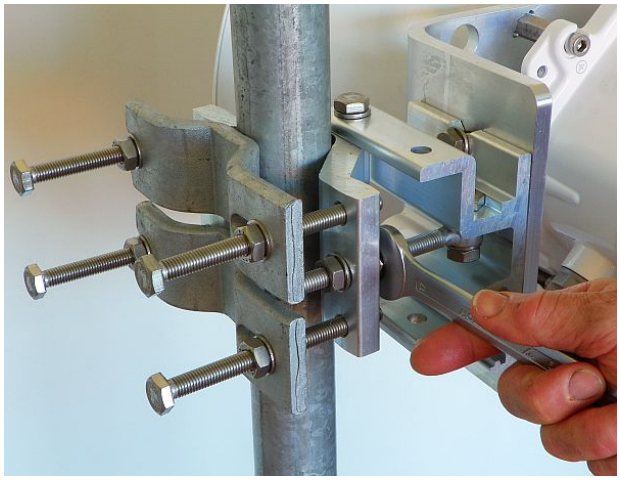


Fig. 6.18: Horizontal adjustment of the antenna direction

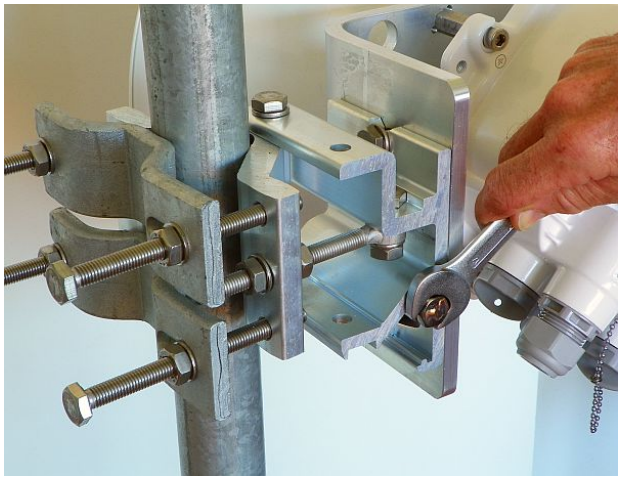


Fig. 6.19: Vertical adjustment of the antenna direction

g. After pointing the antenna in the right direction tighten the bolts on the bracket on the axes of rotation (part No. 6 and 11). Then check again that all other bolts have been sufficiently tightened. We can now proceed to connect the FOD unit to the user network.

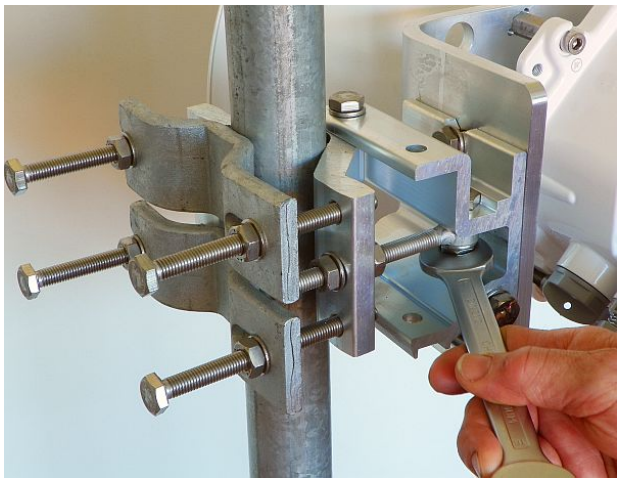


Fig. 6.20: Tightening the axis at the fine adjustment bolt

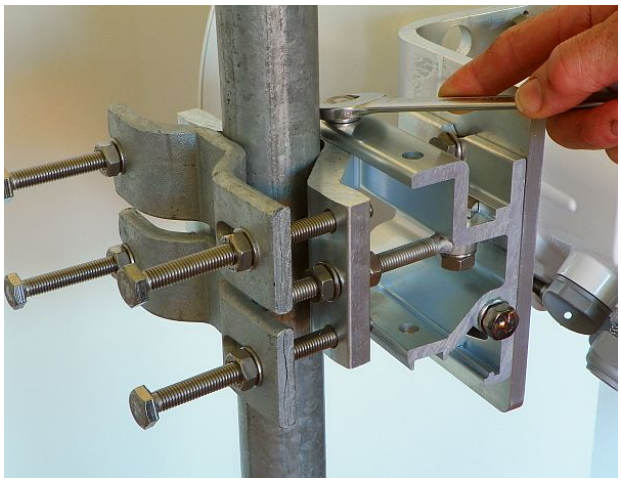


Fig. 6.21: Tightening the axis at the bracket

6.2.3. Lubrication and preservation of the antenna pivot

Before fitting the FOD unit bush onto the antenna pivot ensure that the "O" ring (part No. 1) is in the correct position. It is also essential to prevent moisture getting in between these two parts. This moisture could cause oxidation which would complicate disassembly of this mechanical coupling in the future. For this reason we need to treat these surfaces with the grease which is supplied in the box marked "SILIKONOVE MAZIVO". If you use a different grease for lubrication then it should be a Teflon or a silicon grease.

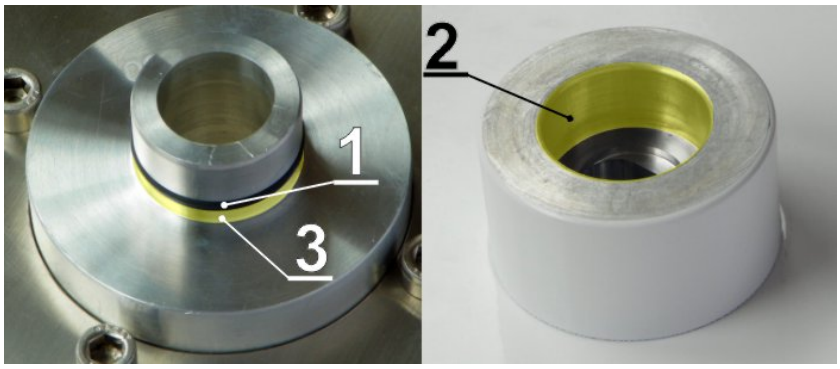


Fig. 6.22: Grease points on the antenna pivot and FOD unit bush

Grease the internal area of the bush on the FOD unit (2) and the "O" ring (1) with a thin even layer that allows the pin to slide easily into the bush without damaging the "O" ring. Grease the area beyond the "O" ring on the antenna pin (3) with a thicker layer so that it fills the gap caused by the play between the pin and the bush (max. 0.1 mm/ø) thus preventing moisture getting in. Installation should be carried out according to the antenna installation description – see point f of this description.

The tub with grease is supplied with the RAy2 units.

6.2.4. Flexible waveguide

Any type of antenna may be connected to the RAy2 unit using a flexible waveguide. Flexible waveguide mounting kit can be ordered as an accessory part.

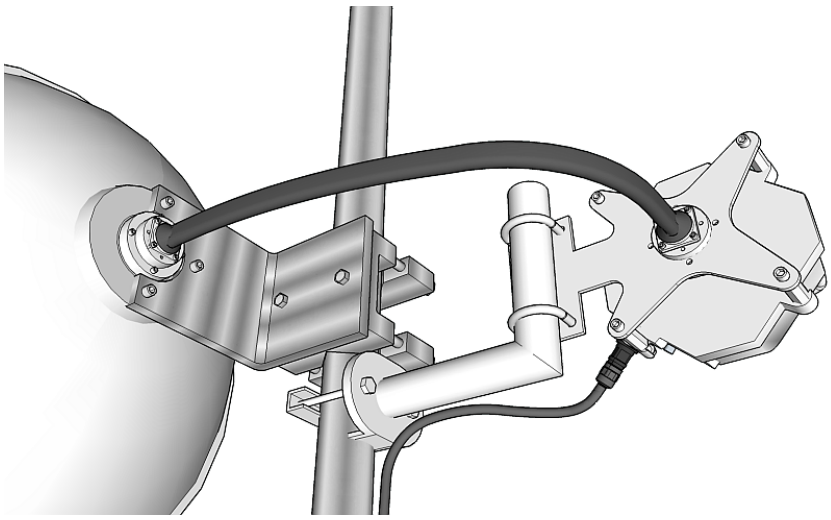


Fig. 6.23: Flexible waveguide assembly

6.3. Connectors assembly

The FOD communication unit can be connected to the user network by metallic or fibre Ethernet cable.

The unit is equipped with those connectors:

- ETH1+POE – Gigabit metallic Ethernet port. This port can power the unit with any Power over Ethernet power source working according to IEEE 802.3at standard.
- ETH2 – Slot for user exchangeable SFP module. A wide range of optical modules is available. Both single or dual mode transceivers can be used. The SFP module with metallic RJ45 interface can be used as well. Please see the Important notice.
  The SFP status LED is located just next to the slot.
- P – DC power connector.
  HW button for service purposes.
- S – USB service connector.
  RSS voltage output connectors.

Fig. 6.24: FOD communication unit connectors

Important

Before connecting the FOD communication unit to the supply (to the user network) the FOD unit must be grounded according to Section 6.4, “Grounding”.

Assembly procedure:

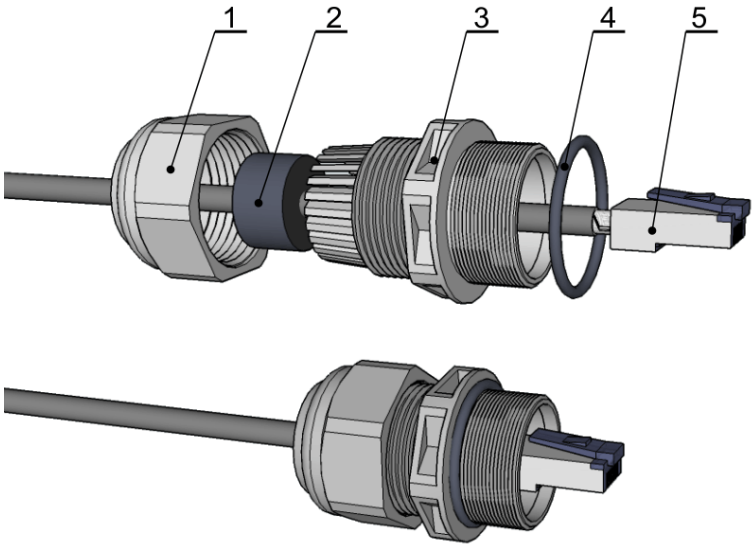


Fig. 6.25: Bushing and connector assembly

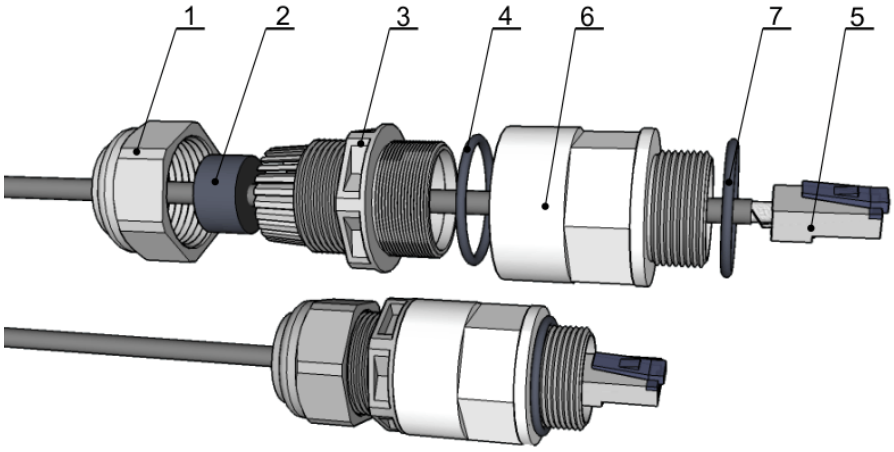


Fig. 6.26: Bushing incl. lengthening and connector assembly

- Put on the cable: the nut No.1, rubber sealing No.2, bushing No.3 and O-ring No.4.
- Attach the appropriate connector No.5 to the cable.
- Plug the connector No.5 into the RAy2 unit.
- Screw the bushing No.3 with the sealing O-ring into the RAy2 unit.
- Move the rubber sealing No.2 along the cable to fit in the bushing. Screw the nut No.1 on bushing No.3.
- (If you use extension ring No. 6 lubricate its thread with grease.)

Disassembly procedure:

- Release the nut No.1
- Remove the rubber sealing No.2
- Unscrew the bushing No.3 with O-ring No.4 (and extension No.6 with O-ring No.7).
- Remove the connector.

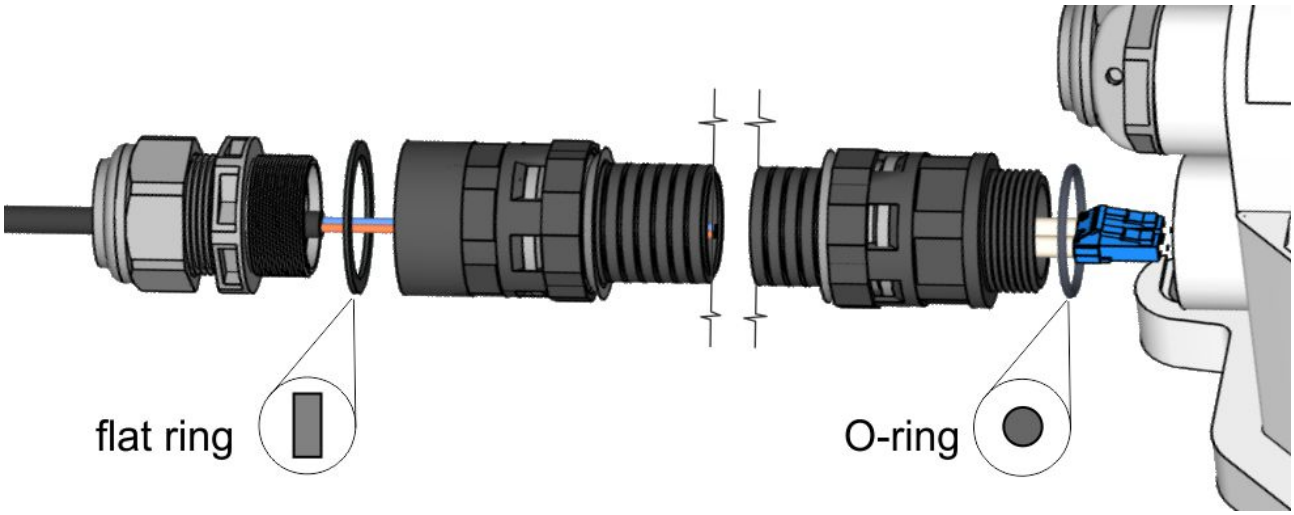


Fig. 6.27: Bushing including long lengthening

All necessary parts are delivered as an accessory SET-RAY2-CON-B. If the lengthening is needed use the extension SET-RAY2-EXT35 containing the parts No.6 and No.7 or use the longer extension SET-RAY2- EXT-F50.

The rubber sealing is delivered with three different internal diameters to fit different cable diameters. The rubber is diagonally cut to enable sealing of cables with preinstalled connectors.

Important

- All bushings and plugs (including the original plugs in the ports) must be fitted with O-rings and carefully tightened. Failure to do so may result in moisture accessing the internal workings. In such a situation the functionality cannot be guaranteed.
- Before screwing extension ring (part No.6) into the RAy2 housing, lubricate its thread with grease.
- When using other bushing or connector than the delivered there is a danger of bad seal or damaging the connector. Interior space can be small.

6.4. Grounding

The lightning and overvoltage protection system example, designed in accordance with regulation CSN EN 62305.

1. Where possible the antenna should be located in an LPZ 0B protection zone with the use of a local or artificial air termination device for protection against direct lightning strikes.
2. When meeting conditions for ensuring electrical insulation (distance from the lightning conductor) in accordance with article 6.3, it is not recommended to ground the load-bearing structure and antenna to the external air termination network. Grounding should be attached to the protective system of the internal LV wiring or grounded internal structures using a CYA 6 mm^2 bonding conductor , see Fig. 6.28, “Grounding installation 1”

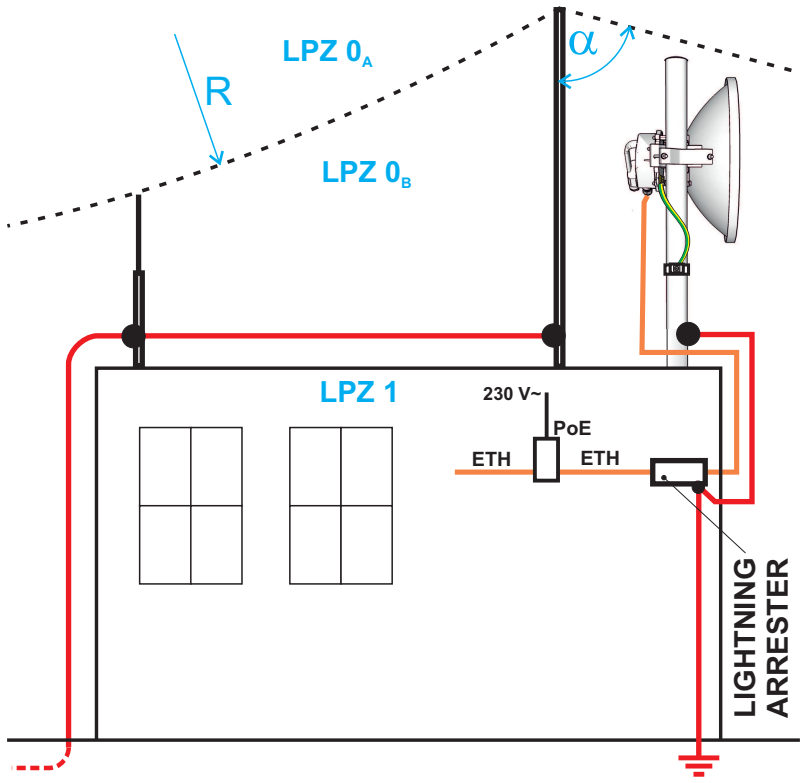


Fig. 6.28: Grounding installation 1

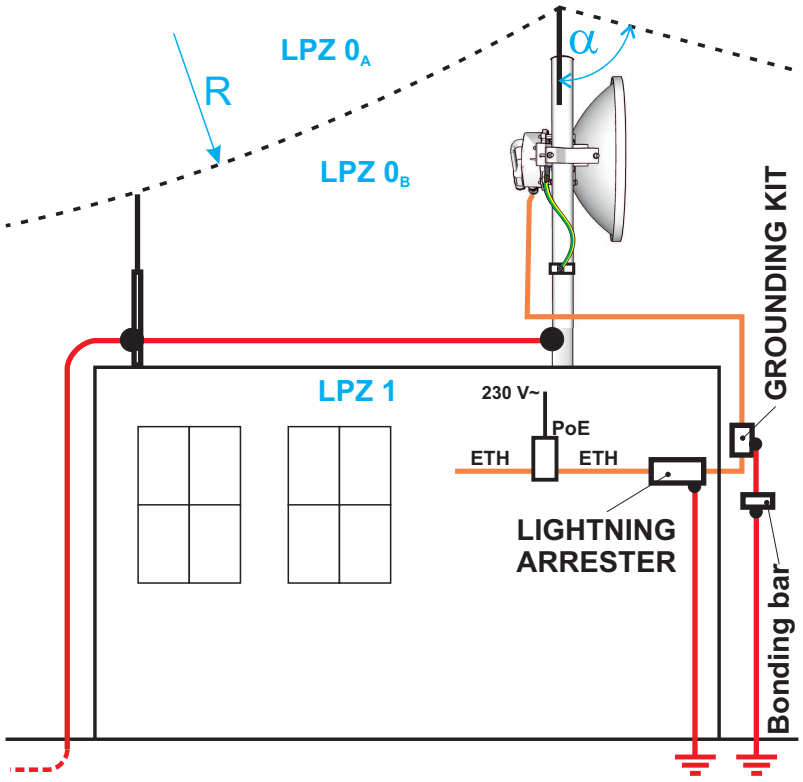


Fig. 6.29: Grounding installation 2

3. If it is not possible to set up conditions of electrical insulation in accordance with article 6.3 we recommend connecting the load-bearing structure at roof level to the external air termination network via an 8mm diameter FeZn conductor and shielding the data cable before entry to the building with a grounding kit and CYA 6 mm^2 conductor to the bonding bus, and if not already set up then also to the external air termination network, see Fig. 6.29, “Grounding installation 2”

4. If there is not an external LPS on the building we recommend routing lightning current through an 8mm FeZn conductor to a common grounding system, or to a separate grounding electrode with a ground resistance up to 10 Ω.

5. For limiting the overvoltage transferred over the data cable and into the building we recommend fitting surge protection at the interface between zones LPZ 0 and LPZ 1 connected via a CYA 4 mm^2 conductor to the same grounding point as the antenna or the antenna mast.

6. We recommend protecting the PoE power supply from overvoltage on the LV side with suitable class D surge protection.

The RAy2 unit is grounded to the flange at the fixing screws using an M8 screw. An insulated copper cable with a minimum cross-section of 6 mm^2 terminated with a terminal lug is used as a protective conductor. The conductor should have a green/yellow plastic cover along its whole length. For grounding a RAy grounding kit can be ordered as an accessory (see Chapter 4, *Accessories*) containing a grounding terminal ZSA16, 40 cm grounding strip 15 mm wide, and 100 cm of cable with grounding lugs. For instructions on installing terminals see the datasheet RAy grounding kit[1]. A qualified person must install the antenna.

Racom supplies surge protection for installation on Ethernet cables entering buildings. For more details see Surge protection[2].

Additional safety recommendations

- Only qualified personnel with authorisation to work at heights are entitled to install antennas on masts, roofs and walls of buildings.

- Do not install the antenna in the vicinity of electrical wiring. The antenna and bracket should not come into contact with electrical wiring at any time.

- The antenna and cables are electrical conductors. During installation electrostatic charges may build up which may lead to injury. During installation or repair work to parts of the antenna lead, bare metal parts must be temporarily grounded.

- The antenna and antenna cable must be grounded at all times. See Section 6.4, “Grounding”.

- Do not mount the antenna in windy or rainy conditions or during a storm, or if the area is covered with snow or ice.

- Do not touch the antenna, antenna brackets or conductors during a storm.

[1] http://www.racom.eu/download/hw/ray/free/eng/07_prislusenstvi/ZSA16-en.pdf
[2] http://www.racom.eu/eng/products/microwave-link.html#accessories

Fig. 6.30: Grounding kit for S/FTP 4+2 cable

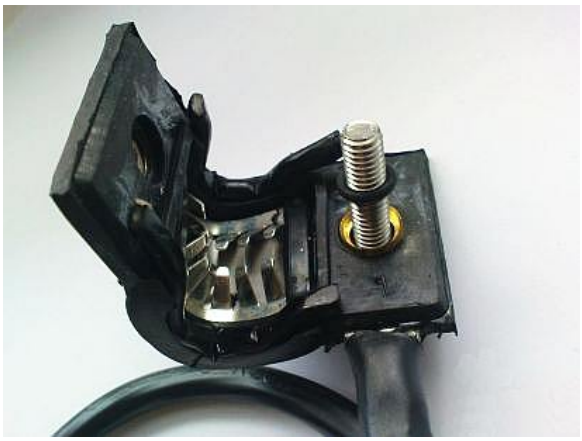


Fig. 6.31: Grounding kit detail

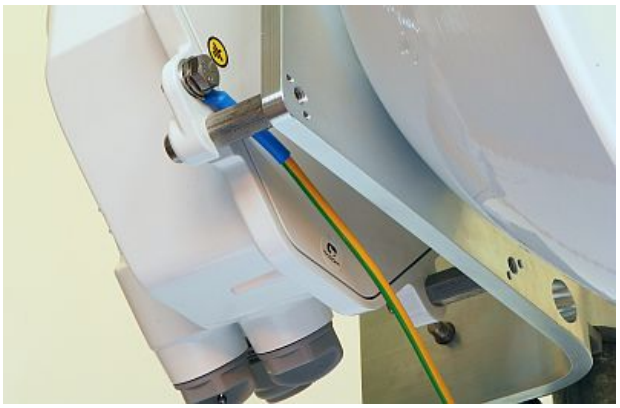


Fig. 6.32: Protective conductor at the FOD unit

Fig. 6.33: Grounding the FOD unit

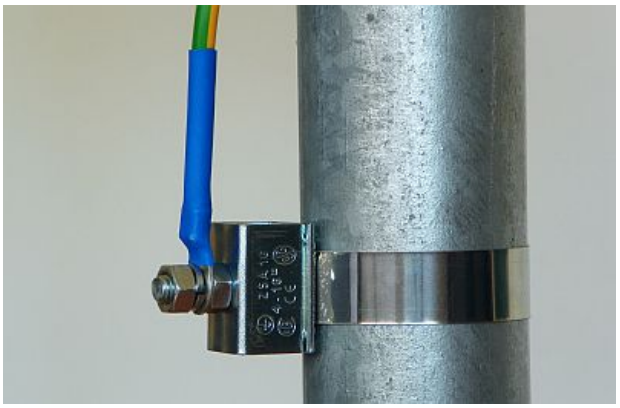


Fig. 6.34: Protective conductor at the mast on a ZSA16 terminal

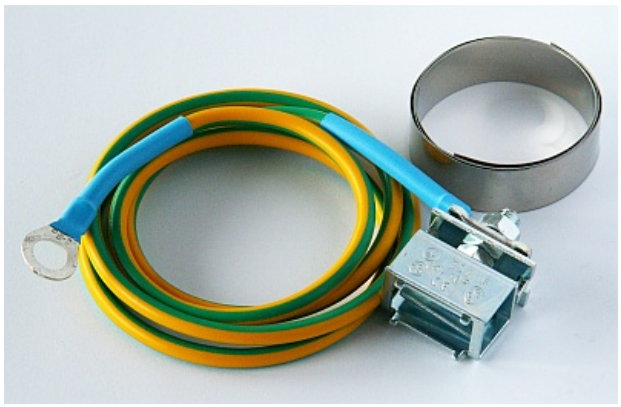


Fig. 6.35: RAy grounding kit

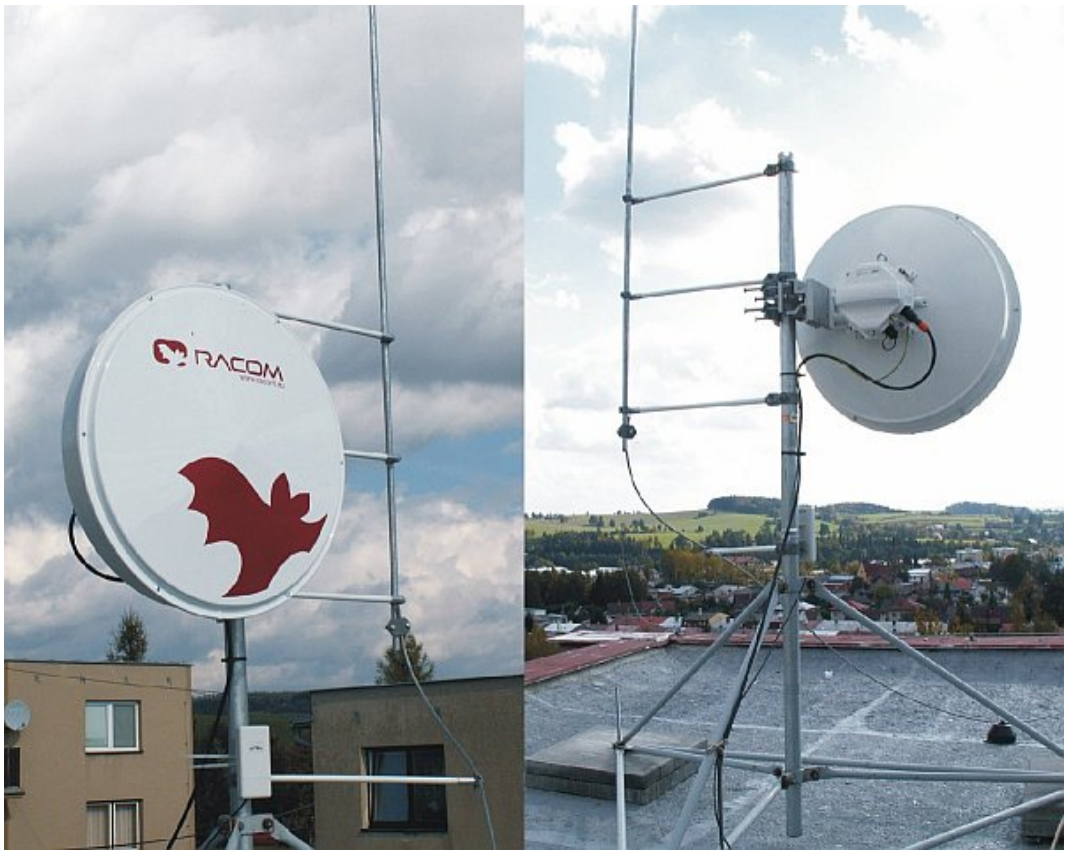


Fig. 6.36: Separated lightning conductor

Note - It is always better not to install the microwave unit directly under the lightning conductor holders. There is lower probability of unit being polluted by birds.

It is necessary to install the Ethernet lead so that there is no excessive mechanical stress applied on the connector bushing:

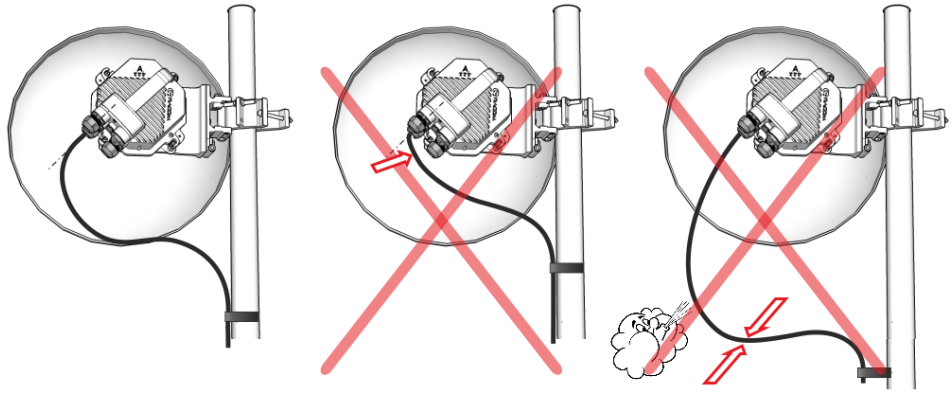


Fig. 6.37: Example of a correct lead installation.

6.5. Start up

Connect a power supply to the installed FOD unit and connect the configuration PC. Use an internet browser (such as Mozilla Firefox) to enter the configuration menu.

6.5.1. Noise on the site

This is particularly true for installation of links working in free bands, where the user has no secured frequency.

Analyse the level of noise in the individual channels using the spectrum analyzer under *Tools – Live data – Frequency spectrum analyzer*. If necessary adjust the choice of working channel on the basis of the results.

While doing so respect the rule that in one location all units emit a signal in the Upper part of the range and receive it in the Lower part of the range, or the other way round. A transmitter must not be installed in the part of the spectrum where other units function as receivers.

6.5.2. Directing antennas

If it is possible, use a narrow channel, low modulation and high power for the first antenna directing alignment. Working on both ends of the link simultaneously is favourable. Connect a voltmeter to the connectors and observe RSS changes in 2 V DC range. A stronger signal corresponds to lower voltage. Alternate units on both sides and slowly adjust the antenna vertically and horizontally to find the position with the strongest reception. At the same time look for the main signal maximums. To differentiate between the main and the side maximums refer to the Main and side lobes paragraph.

RSS measurement

For correctly setting the bridge and positioning it in the right direction it is advisable to connect a PC and use the diagnostic capabilities of the RAy2 station. In uncomplicated cases it is enough to connect a voltmeter via connectors and adjust to the lowest indicated voltage. Voltage is calibrated according to signal strength. E.g.:
RSS -65 dBm corresponds to voltage 0.65 V,
RSS -80 dBm corresponds to voltage 0.80 V etc.

Fig. 6.38: RSS connectors

Fig. 6.39: RSS connectors - connecting a voltmeter

Main and side lobes

Directional antennas have a specific angle within which radio waves can be transmitted or received (Angle of Tx/Rx).

The strongest signal is emitted in a forward direction; the main lobe is a graphical representation of its direction of travel and strength.

However signals are also emitted and received from unwanted directions through side lobes. In receiving antennas this is a highly significant factor contributing to the level of interference in a radio network (See Fig. 6.40, “Antenna lobe diagram”).

Fig. 6.41, “Signal strength graph” provides an indication of comparative signal strength from different beams emitted from a directional antenna.

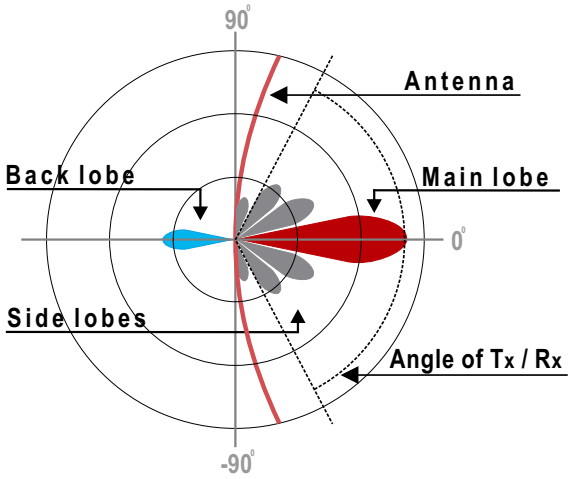


Fig. 6.40: Antenna lobe diagram

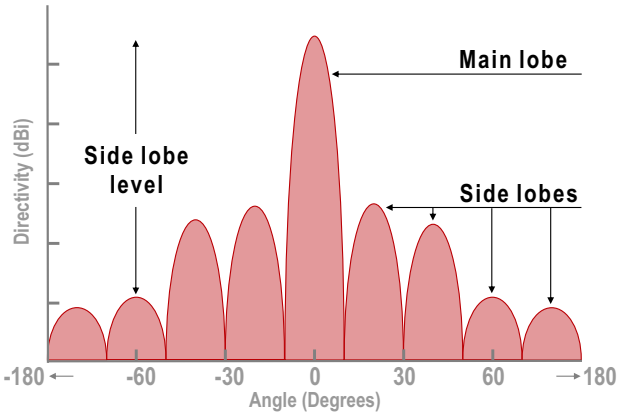


Fig. 6.41: Signal strength graph

Placing the antennas to the correct antenna alignment is very important to ensure the strongest signal is received:

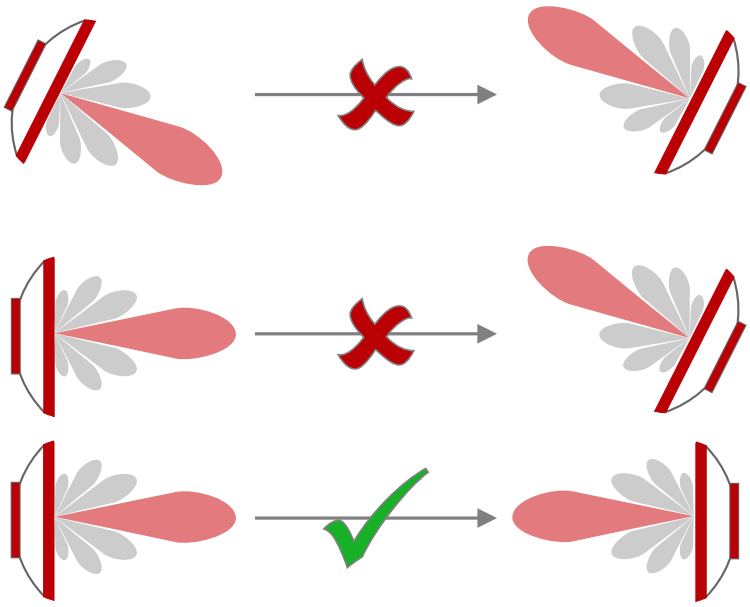


Fig. 6.42: Correct alignment diagram

Examples

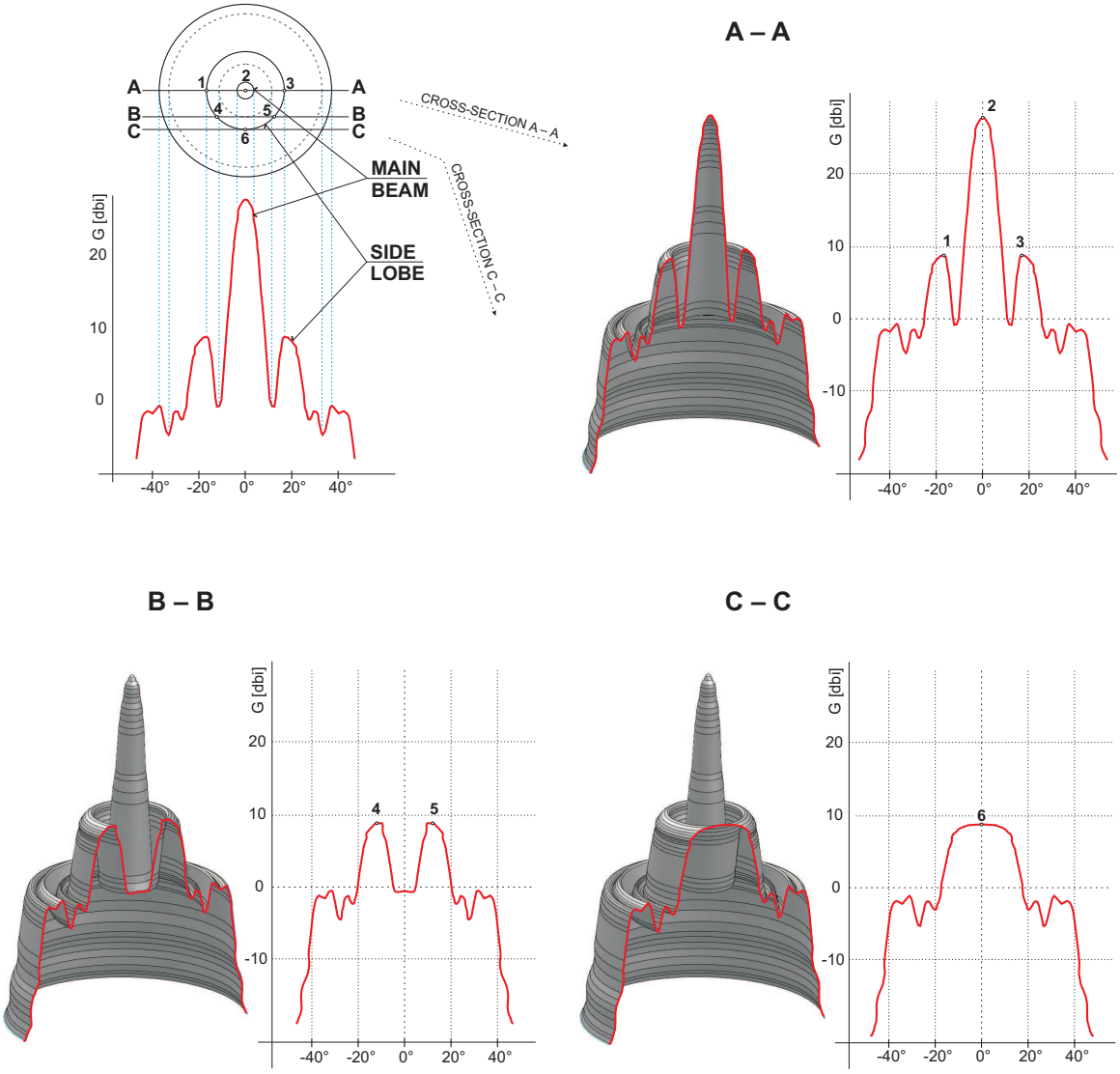


Fig. 6.43: Radiation diagrams

Both antennas should be oriented towards each other using the peaks of the radiation diagram. Adjust the antenna alternately in the horizontal and vertical axes and monitor the resulting signal strength. Use the calculation of the expected RSS with the precision of several dBm as guidance. Side lobes transmit a signal ca 20 dBm weaker, see the Microwave link Calculation[3].

[3] http://www.racom.eu/eng/products/microwave-link.html#calculation

The resulting RSS helps distinguish between the states A-A and C-C which appear similar. It also helps in situations where simple search for a maximum doesn't work as shown in the illustration "incorrect adjustment".

Real radiation diagrams are more complex, especially in that they run differently in horizontal and vertical axes. The basic steps for determining the main radiation lobe however stay valid. For example:

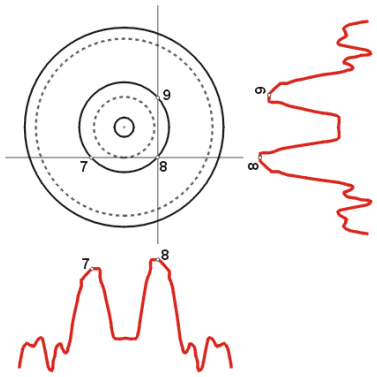


Fig. 6.44: Radiation diagram – incorrect adjustment

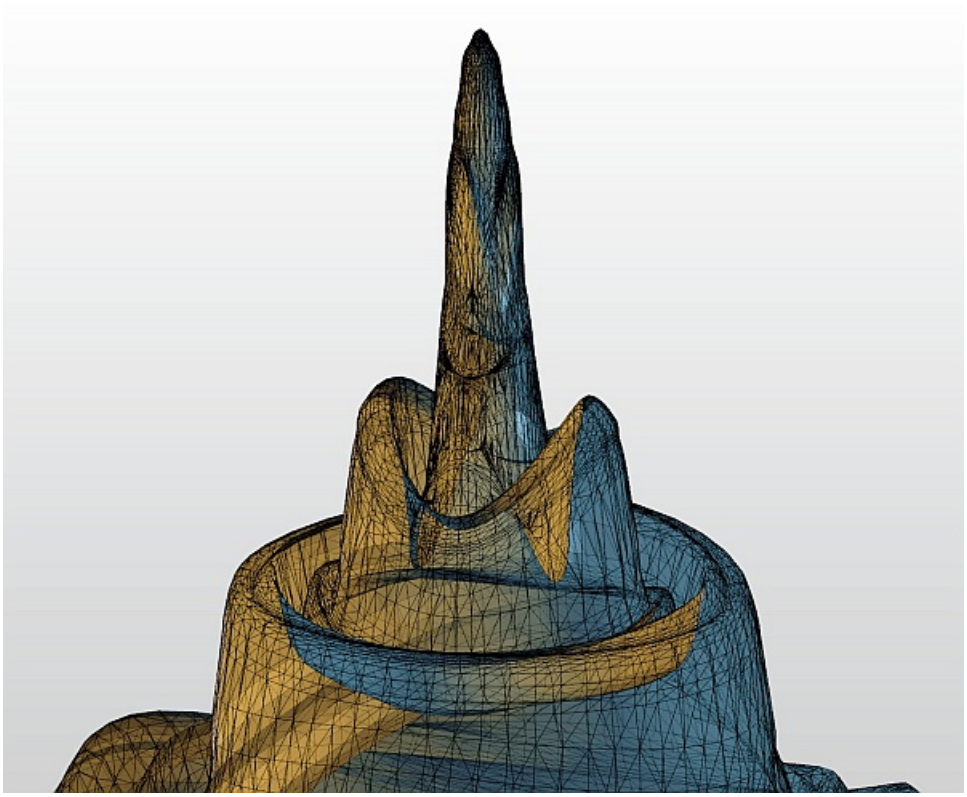


Fig. 6.45: 3D example of more complicated Radiation Pattern

6.5.3. Link test

Basic parameters of the link are shown in the menu *Status – Brief*, its quality is characterized by RSS and SNR. Values on Status screens can be refreshed manually by pressing the Refresh button or in real time with a period of several seconds after activating the Start button. Press the Stop button to terminate the periodic refresh of values.

The RSS, SNR and BER values can also be viewed on the screen *Tools – Live data – Bar indicators*. After pressing the Start button, values will be refreshed with a period of one second.

After installation, it is good to reset the statistics using the *Clear stats* button in menu *Status – Detailed*. This allows easier diagnostics of the link's reliability over time.

6.5.4. Parameters setup

After both antennas have been aligned, setup operation parameters for the link. In the case of links operating in the free band, setup the parameters based on survey results from the tool *Tools – Live data – Frequency analyser*. In the case of links operating on a licensed band, setup the parameters based on the assigned license:

- Bandwidth
- Channel Selection (TX / RX channel)
- Modulation (TX modulation) – ACM is recommended. When selecting fixed modulation it is necessary to account for the fade margin. If fixed modulation is setup close to a possible maximum, then a deterioration in RSS could endanger the link both for data transfer as well as service access.
- Transmit power (TX power), or ATPC
- Verify and record IP addresses
- Define access channels – https / telnet / ssh / ssh with password
- Check the users password settings.

Restart both units by interrupting their power supply and verify the status of the link. This verifies that all parameters have been stored correctly in the memory.

Select *Tools – Maintenance – Backup – Settings (Local & Peer) - Download* and save the configuration to backup file "cnf_backup.tgz".

This completes the installation. Further configuration can be performed remotely.

7. Configuration

7.1. Introduction

Controls

The following configuration buttons are used for configuration:

Apply	Apply and save parameters.
Cancel	Set parameters are overwritten with original values.
Refresh	Reload all current values of the unit / both units.
Show defaults	Show values of individual parameters as they are stored in backup configuration (in the buffer). To use any of these values, you must use the *Apply* button.
Show backup	Clicking the button displays the values of individual parameters held in the backup file (*Backup – Settings – Open file upload*). To use any of these values, you must use the *Apply* button. For loading the backup configuration see menu *Tools – Maintenance – Backup*.
Start	Activating automatic refresh fields marked by icon using the *Start* button with the frequency cca 1 sec.
Stop	Use the *Stop* button to stop automatic refresh of displayed information with 1sec period. Date and time values are refreshed anyway.

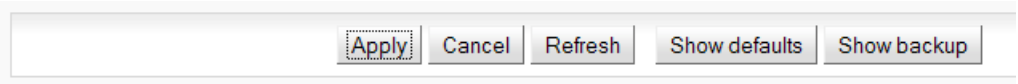


Fig. 7.1: Info Refresh

Help

The microwave link configuration system is equipped with built in Help - see Help section. The Help is accessible in two forms:

- Configuration parameter context help. The help text is displayed in the pop up window after clicking the parameter name.
- The whole user interface help. The help text is displayed within the configuration screen after clicking the *Help* menu.

Secure login

You can login into the configuration interface using either the **insecure http** protocol (default login screen), or the **secure https** protocol. You should select the connection method on the login screen. If the https protocol is used, it is not possible to tap the network communication and acquire the station's login information.

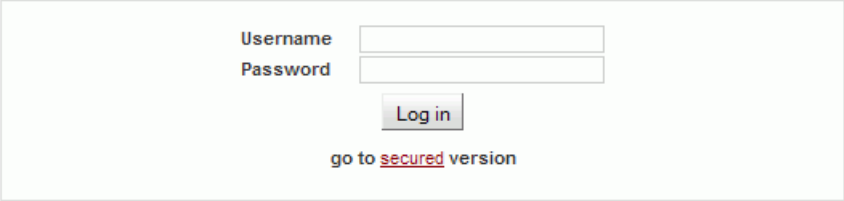


Fig. 7.2: Login

Rollback function

If you interrupt the connection on an operating link by entering inappropriate radio link parameters, the original parameters will be restored after 1 minute. The connection is automatically restored.

7.2. Status bar

Fig. 7.3: Status bar 1

The Status bar is located on the upper part of the screen below the title bar. It consists of 3 fields:

- **Local** unit status (unit assigned to the IP address entered in the browser or CLI)
- Local to Peer **Link** status.
- **Peer** unit status.

Local and Peer field displays:

- Station name according to configuration.
- Actual time valid for respective unit.
- Warning or Alarm icon in case of warning or alarm.

Link field display:

- Status of the link between both sides of the microwave link.
- Warning icon when the link is not capable of user data transfer.

The Link status can be one of the following values:

UNKNOWN	Unit start up. The initialization is not yet finished.
SETUP	Unit initialization according to valid configuration.
SINGLE	Unit in operation status. Link to peer unit is not established.
CONNECTING	Connection to peer unit in progress.
AUTHORIZING	Authorization of the peer unit in progress.
OK	Link is connected. Peer unit is authorized.
ANALYZER	Spectrum analyzer mode active. User data are not transferred.

All link states except for the state of OK are highlighted with a triangle.:

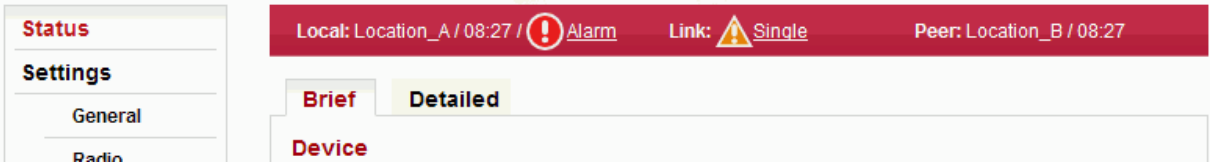


Fig. 7.4: Status bar 2

Example of a complete page - status bar, menu and control buttons:

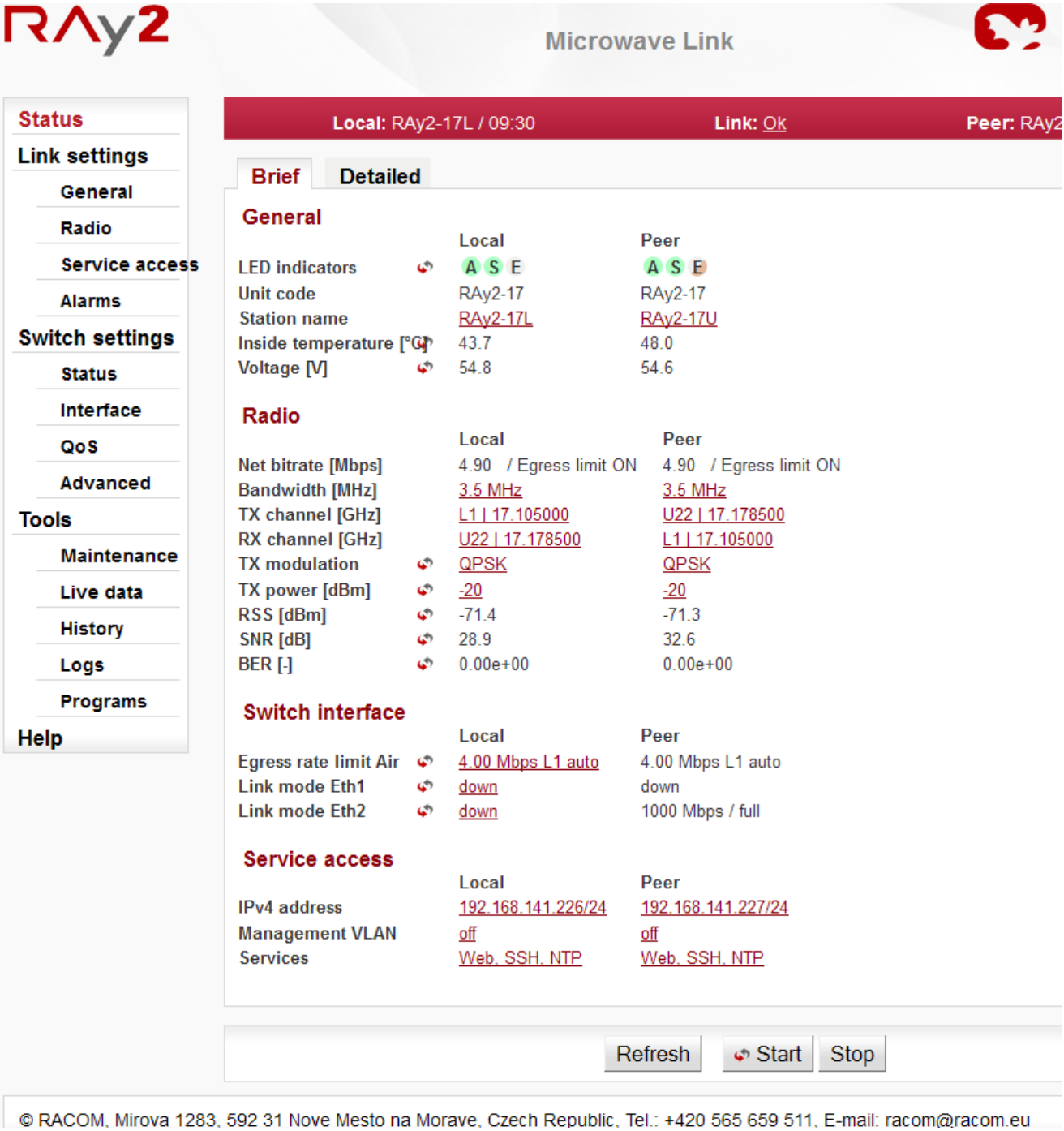


Fig. 7.5: Page example

7.3. Status

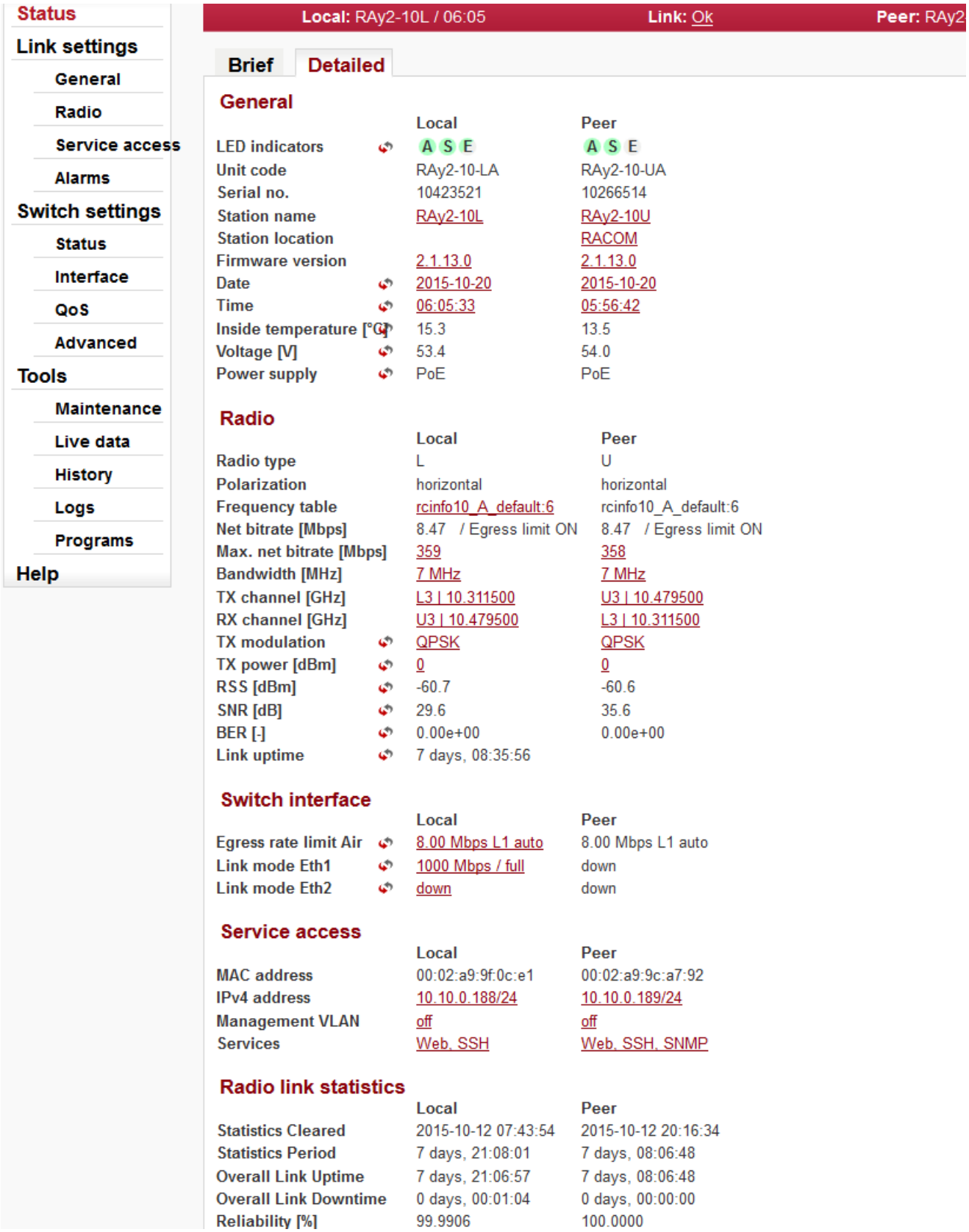


Fig. 7.6: Menu Status

The *Status* menu provides basic information about local and remote station. Informations is valid the moment the page is open, or the Refresh button is hit.
The *Status – Brief* tab shows only the most important values whereas the *Status – Detailed* tab provides further details. Below is a list of all values according to the tab *Status – Detailed*.
The icon marks fields which are automatically updated with 30 sec period (or 1 sec when the *Start* button is active).

7.3.1. Status - General

LED indicators	Unit status indication		
	A - AIR	Green Red	- Radio link OK - Radio link interrupted
	S - SYS	Green	- System OK
	E - ETH	Green Orange	- ETH1 port - Link 10/100/1000 - ETH2 port - Link 10/100/1000
Unit code	Unit type indicator.		
Serial no.	Unit serial number.		
Station name	Station name assigned by user.		
Station location	Station location assigned by user.		
Firmware version	Unit's firmware version.		
Date, Time	The internal real-time clock. The clock is set manually or it is synchronized with NTP server and set for both units.		
Inside temperature [°C]	Temperature inside the unit (on the modem board).		
Voltage [V]	Unit's power supply voltage level.		
Power supply	The power supply input the unit is powered from. PoE - unit is powered via Ethernet cable plugged into port "ETH1+POE". AUX - unit is powered via DC cable plugged into port "P".		

7.3.2. Status - Radio

Radio type	Radio unit type: L (Lower) or U (Upper) part of the frequency band.
Polarization	Horizontal or vertical polarization based on the physical installation. Indicates the polarization of the received signal. Local and Peer are indicated separately. The proper position of the cable is sideways down. Notice for RAy2-17 and RAy2-24 links: One side of the link must be installed in vertical polarization and the other in horizontal polarization.
Frequency table	Displays the currently used frequency table in format <name:version>.
Net bitrate [Mbps]	Current transfer capacity of radio channel for user data.
Max. net bitrate [Mbps]	The maximum RF channel capacity according to installed feature key.
Bandwidth [MHz]	One of the standard channel widths can be selected. This parameter must be set identically in local and remote.
TX and RX channel [GHz]	Used channels. Both number of the channel and frequency in GHz are listed.
TX modulation	Modulation type currently used for transmitting. When adaptive modulation is enabled, the ACM letters are displayed as well as information about

	maximum permitted modulation: “current modulation ACM / maximum modulation”
TX power [dBm]	Current output power on the RF channel in dBm. If ATPC is enabled, the ATPC letters are displayed as well as information about maximum permitted power: “current power ATPC / maximum power”
RSS [dBm]	Received signal strength. If ATPC is enabled, the ATPC letters are displayed as well as information about threshold value for activation of power

	control loop: “current RSS ATPC / threshold RSS”
SNR [dB]	Signal to Noise Ratio. If ATPC is enabled, the ATPC letters are displayed as well as information about threshold value for activation of power control loop: “current SNR ATPC / threshold SNR”
BER [-]	Bit Error Rate is registered at the receiving end; instantaneous value.
Link uptime	Time elapsed since the current link connection has been established.

7.3.3. Status - Switch interface

Egress rate limit Air

Status of the Egress rate limitter on the Air interface. The traffic can be limitted according to bits per second or frames per second.

Message format for bits per second: "xx.xx Mbps Ly auto" where:

xx.xx Mbps	Egress speed limit.
Ly	L1/L2/L3 which Ethernet layer is used for speed calculation.
auto	gives information about active *Speed guard* function.

Message format for frames per second: "xx.xx fps" where:

xx.xx fps	Egress frames per second limit.

Link mode Eth1, 2 Status of ethernet interface. Current bit rate (10 = 10BASE-T, 100 = 100BASE-TX and 1000 = 1000BASE-T) and state of duplex (FD = full duplex, HD = half duplex).

7.3.4. Status - Service access

MAC address	HW address of the Ethernet module.
IPv4 address	IP address in the standard dotted decimal notation, including the bit width of netmask after the forward slash.
Management VLAN	Service access via VLAN management only.
Services	Services enabled for unit management and monitoring (Web, Telnet, SSH, SNMP, NTP).

7.3.5. Status - Radio link statistics

Information on statistical data:

Statistics Cleared	Time of log clearing.
Statistics Period	Period of log refresh.

Radio link statistics:

Overall Link Uptime	Overall time the link has been connected.
Overall Link Downtime	Overall time the link has been disconnected.
Reliability [%]	The ratio of *Uptime* and *Downtime*.
Current Link Uptime	Current time the link has been connected.
The Longest Drop	The longest downtime period recorded.
The Last Drop	Length of the last link interruption.
Number of Drops	Number of link interruptions.

7.4. Link settings

7.4.1. General

Setup of general parameters of the link.

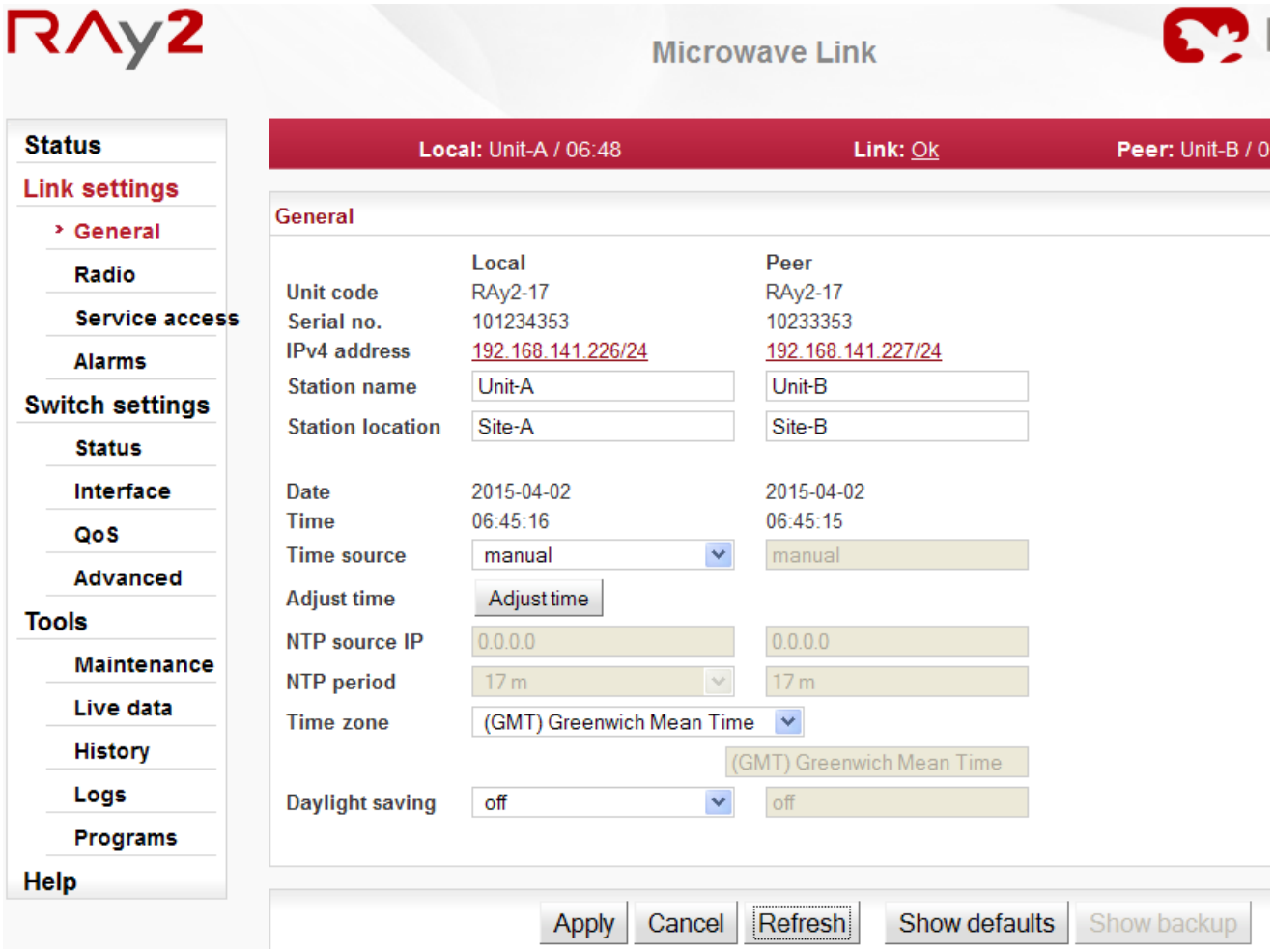
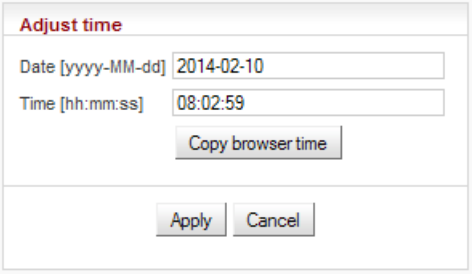


Fig. 7.7: Menu Link settings – General

Unit code	Unit type indicator.
Serial no.	Unit serial number.
IPv4 address	IP address in the standard dotted decimal notation, including the bit width of netmask after the forward slash.
Station name	Station name assigned by user.
Station location	Station location assigned by user.
Date, Time	The internal real-time clock. The clock is set manually or it is synchronized with NTP server and set for both units.
Time source	Time synchronization source setup. Manual setup or NTP protocol use. For easier diagnostics of link operation, it is recommended to use the NTP time synchronization.

Adjust time — Manual time setup. Use the dialog box to manually set the current date and time. You can copy time from browser (local PC).



NTP source IP — IP address of the time synchronization server.

NTP period — Time synchronization interval.

Time zone — Time zone

Daylight saving — Enable daylight saving time

Note

When the time zone and/or daylight saving time is changed, the original values set in the RAy unit are kept. The actual change takes place after OS restart in order to prevent unexpected states related with local time change.

7.4.2. Radio

Setup of general parameters of the radio link.

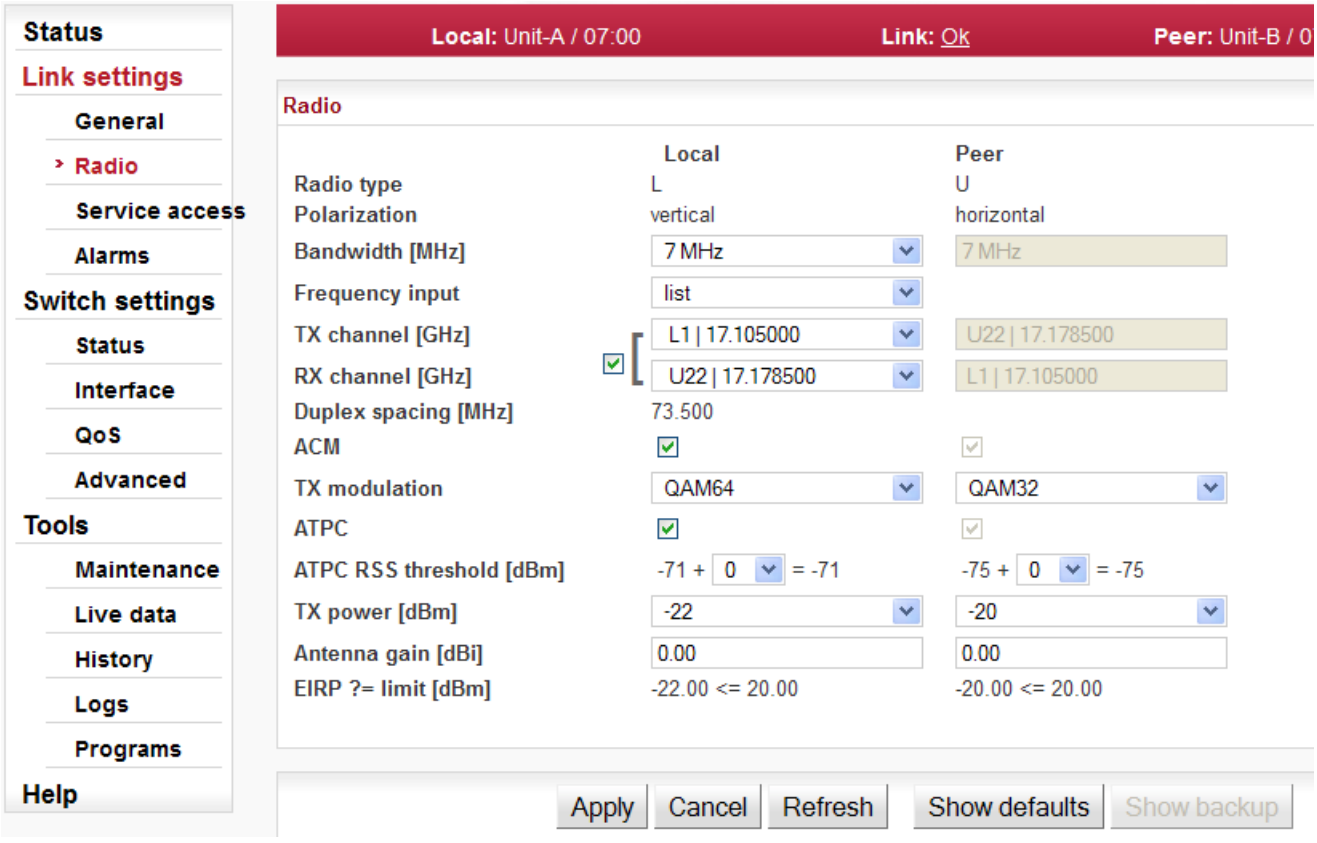


Fig. 7.8: Menu Link settings – Radio

Radio type	Radio unit type: L(ower) or U(pper) part of the frequency band.
Polarization	Horizontal or vertical polarization based on the physical installation. Indicates the polarization of the received signal. Local and Peer are indicated separately. The proper position of the cable is sideways down. Notice for RAy2-17 and RAy2-24 links: One side of the link must be installed in vertical polarization and the other in horizontal polarization.
Bandwidth [MHz]	One of the standard channel widths can be selected. This parameter must be set identically in local and remote.
Frequency input	Enable manual input (if supported). TX and RX frequencies [GHz] are manually entered. It is possible to disconnect the TX-RX lock and select TX and RX channels individually. Corresponding channels at peer unit are set automatically.
TX channel [GHz] **RX channel [GHz]**	TX and RX channels are selected from a list of channels. The basic configuration has the TX and RX options interconnected. In this case the basic duplex spacing between channels is preserved and by selecting one channel, the other three are defined as well. For units operating in free bands, it is possible to disconnect the TX-RX lock and select TX and RX channels individually. Corresponding channels at peer unit are set automatically. NOTE: Non-standard duplex setting leads to non-effective use of the spectrum.
Duplex spacing [MHz]	Information about duplex spacing of TX and RX channel.
ACM	Enable automatic control of modulation.
TX modulation	Modulation level for TX channel. You can select in range from QPSK (high sensitivity for difficult conditions) to 256QAM (high speed under appropriate conditions). With ACM enabled the modulation will automatically operate from QPSK to the selected modulation.
ATPC	Enable automatic control of RF power. Power is regulated towards lower level while maintaining signal level high enough not to affect current degree of modulation.
ATPC RSS threshold [dBm]	The ATPC algorithm controles the output power according to RSS of the peer unit. The lowest allowed RSS (the threshold) is approx. 10 dBm above declared sensitivity for BER 10^{-6}. If necessary, it is possible to use this parameter to move the threshold slightly up or down.
TX power [dBm]	RF output power. With ATPC enabled this parameter defines maximum RF power level.
Antenna gain [dBi]	Valid only for RAy2-17 and RAy2-24 links. Gain of used antenna. It is used to calculate approximate EIRP.
EIRP ?= limit [dBm]	Valid only for RAy2-17 and RAy2-24 links. Approximate calculation of EIRP. Number on the right shows the allowed EIRP limit. Sign between numbers gives information on compliance / noncompliance with allowed EIRP limits.

7.4.3. Service access

Services

Access routes for link configuration.

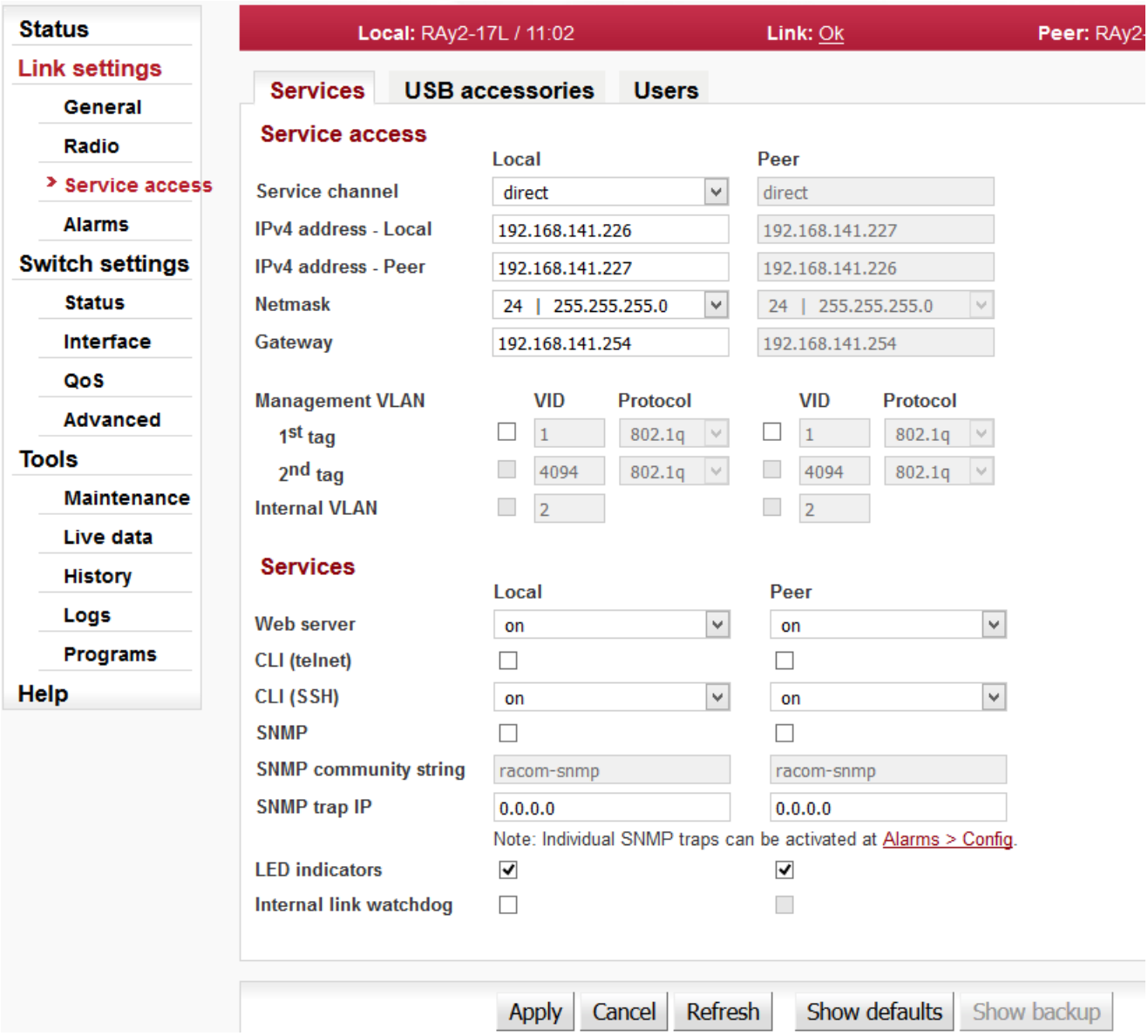


Fig. 7.9: Menu Link settings – Service access – Services

Service channel

There are two modes of accessing the internal management system of the microwave link: standard and direct

standard:

Both units are configured with the separate IP addresses, Netmasks, Gateways and Management VLANs. IP addresses of both units doesn't have to belong in to the same sub-net. The *Internal VLAN* is required to encapsulate the internal service traffic between both units of the microwave link. There are additional internal service addresses used for this internal service traffic (see *IPv4 address - Local* section for further details).

direct:

Both units are configured with the separate IP addresses but with the **same Netmask, Gateway and the Management VLAN**. IP addresses of both units must belong in to the same sub-net. There is no need for *Internal VLAN* to handle the internal service traffic between both units of the microwave link. No additional internal service addresses exist.

NOTE: It is strongly recommended to use *Management VLAN* to encapsulate and prioritize the management traffic when the *direct* mode is selected. If the *Management VLAN* is not used (while in direct mode), the internal service traffic is NOT prioritized.

IPv4 address - Local Service IP address, by default 192.168.169.169 for L unit and 192.168.169.170 for U unit. Four addresses 169.254.173.236/30 are used for internal communication. Must not be used as service IP address. Those four addresses are not used while *Service channel* is set to *direct* mode.

Unknown IP address For easier identification of service IP address, RAy is equipped with LLDP protocol. This protocol sends a broadcast every 60 seconds with the following information:

Management address	IP address
System Description	Serial number
Chassis Subtype	Type (e.g. RAY2-17-L)
IEEE 802.1 - Port and Protocol VLAN ID	
	Port and Protocol VLAN Identifier: (e.g. 300 (0x012C)) but only if Management VLAN is enabled

The message can be recorded and converted into a readable form using an LLDP client. A suitable tool for this purpose is Wireshark IP traffic analyzing tool, with free licenses available for both Windows and Linux. To locate the message easily, use the Capture filter "ether proto 0x88cc” in Wireshark.

IPv4 address - Peer Management address of the Peer station. This address has to be set up when the *Service channel* is set to *direct* mode.

Netmask Mask for service access, 24 by default.

Gateway Default gateway for service access; empty by default.

Management VLAN Enables access via VLAN management. Blocks access for https, ssh and telnet configuration via untagged packets (without VLAN) making only VLAN access possible. VLAN management is off by default.
WARNING:
By enabling VLAN management, ALL accesses are blocked for configuration using normal (untagged) LAN! During tests, you may enable VLAN management on one unit only (if the *Service channel* = *standard*). Then it is possible to access the link via LAN and VLAN either directly or via radio link.

VID VLAN management id, by default 1. This field must have a value entered even when VLAN management is not active.

Protocol Protocol 802.1q or 802.1ad

Internal VLAN	Valid only for *Service channel* = *standard*: The RAy uses one VLAN id for internal service communication between both units. There are two situations when it might be necessary to change the Internal VLAN id: - Conflict within user data flow when the same VLAN id is already present within a data flow. - Conflict with the internal management address of another RAy unit located at the same site and connected in the same LAN segment. NOTE: The Ethernet frames within this service channel are marked with IEEE 802.1p priority class "7". Default parameters for *QoS* and *Egress queue control* are pre-set to prioritize this service communication channel.
Web server	Allows access via web server (for HTTP and HTTPS protocol). WARNING: after disabling access via web server, you will not be able to access the unit using a web browser!
CLI (telnet)	Enables access via telnet protocol. Provides access to CLI (Command Line Interface) for simple telnet clients. Disabled by default.
CLI (SSH)	Enables access via SSH protocol. Provides secure access to CLI. If preventing unauthorized access to the unit is the number one priority, leave only this server on.
SNMP	Enabling SNMP server. Off by default.
SNMP community string	SNMP community string. Can contain both lower and uppercase letters, numbers, four characters . : _ - and can be up to 256 characters long.
SNMP trap IP	Address for sending SNMP traps. It is possible to record up to 3 addresses separated by commas.
LED indicators	Enable LED status indicators on the body of the unit. You can turn off all LEDs with this option.
Internal link watchdog	Watching over connection of both link units. In case of prolonged failure (10 min) a cold restart is performed (the equivalent of turning off the power). Off by default.

USB accessories

USB service connector can be used as a service port to the Local unit only.
USB to Ethernet and USB to WiFi adapters can be used.

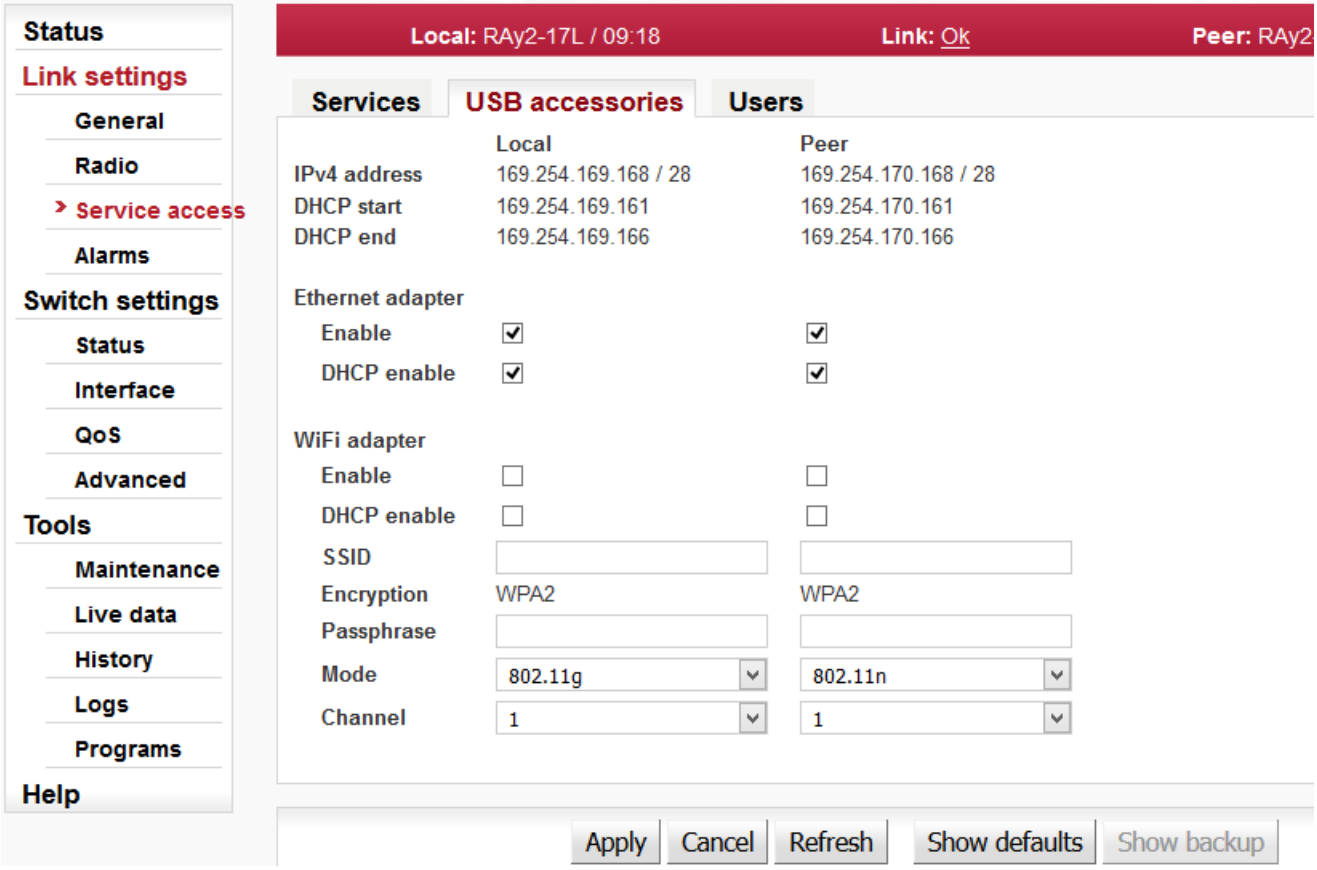


Fig. 7.10: Menu Link settings – Service access – USB accessories

IPv4 address	Unit service management address when connecting via USB port.
DHCP start **DHCP end**	DHCP range for dynamic address allocation of the management client connected via USB port.
Ethernet adapter enable	USB to Ethernet adapter operation Enable/Disable.
Ethernet adapter DHCP enable	DHCP server for the client(s) connected via the USB to Ethernet adapter.
WiFi adapter enable	USB to WiFi adapter operation Enable/Disable.
WiFi adapter DHCP enable	DHCP server for the client(s) connected via the USB to WiFi adapter.
WiFi SSID	Service WiFi SSID can be max 32 characters long.
WiFi encryption	Service WiFi encryption is WPA2.
WiFi passphrase	Service WiFi passphrase has to be 8-64 characters long. The WiFi will not start until it is defined.
WiFi mode	Service WiFi mode can be IEEE 802.11n or IEEE 802.11g
WiFi channel	IEEE 802.11n - channels 1-9 IEEE 802.11g - channels 1-13

Users

List and setup of users. Example menu of the *cli_super* level user.

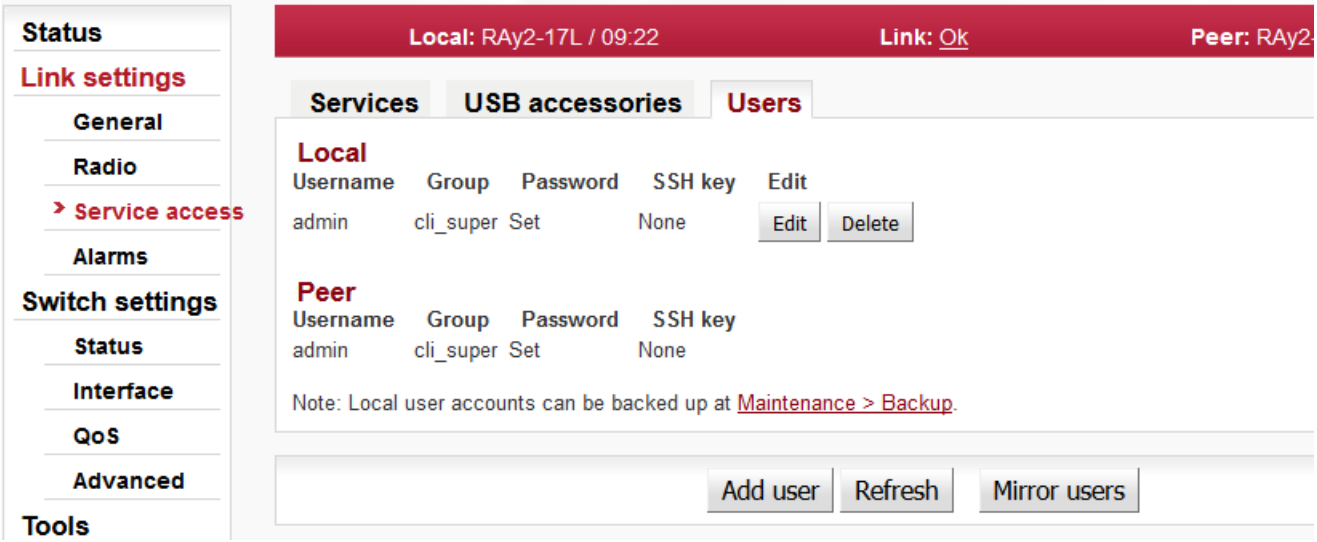


Fig. 7.11: Menu Link settings – Service access – Users

Within the default Factory Settings one user is defined in the system. This user has username **admin** and password **admin** and is assigned the highest level of permissions *cli_super*. This user then assigns other users to the system along with their level of permissions.

Service access has three levels of permissions. Numbers of users that can be defined in the system:

Permissions	No of users
cli_guest	10
cli_admin	10
cli_super	2

Permissions defined in the system	cli_guest	cli_admin	cli_super
Create new user	No	No	Yes
Change own password	Yes	Yes	Yes
Delete user *	No	No	Yes
Copy (Mirror) permissions local to peer	No	No	Yes
Configure and modify link settings	No	Yes	Yes

* The system prevents the user from deleting both cli_super accounts.

The logged on user is shown in the top right of the screen. There can be different users on either end of the link.

Important

It is strongly recommended that the default password admin is changed. Similarly all other users should change their password. Using the CLI, it is appropriate to supplement the SSH key.

Local, Peer List of users on Local and Peer stations.

Username This name is entered at Login to log into the link management.

Group User group to which the user belongs.

cli_guest	Read Only
cli_admin	Configure and modify link settings
cli_super	Configure and modify user accounts and link settings

Password Information about whether user has a password

SSH key Information about whether user has at least one ssh key defined.

Note

More users concurrently

If two or more users work concurrently on the unit any change of configuration settings should be applied by all users. This applies to the menu *Link settings* which works with both, Local and Peer parameters. Notification to other users:

If one user sends the *Apply* command, other users will receive a message: *Configuration changed, please go to Link settings and click Refresh.* Other users can only use the *Apply* command after refreshing *Link Settings*.

Edit use

Clicking *Edit* next to a username opens a screen with configuration of the given account.

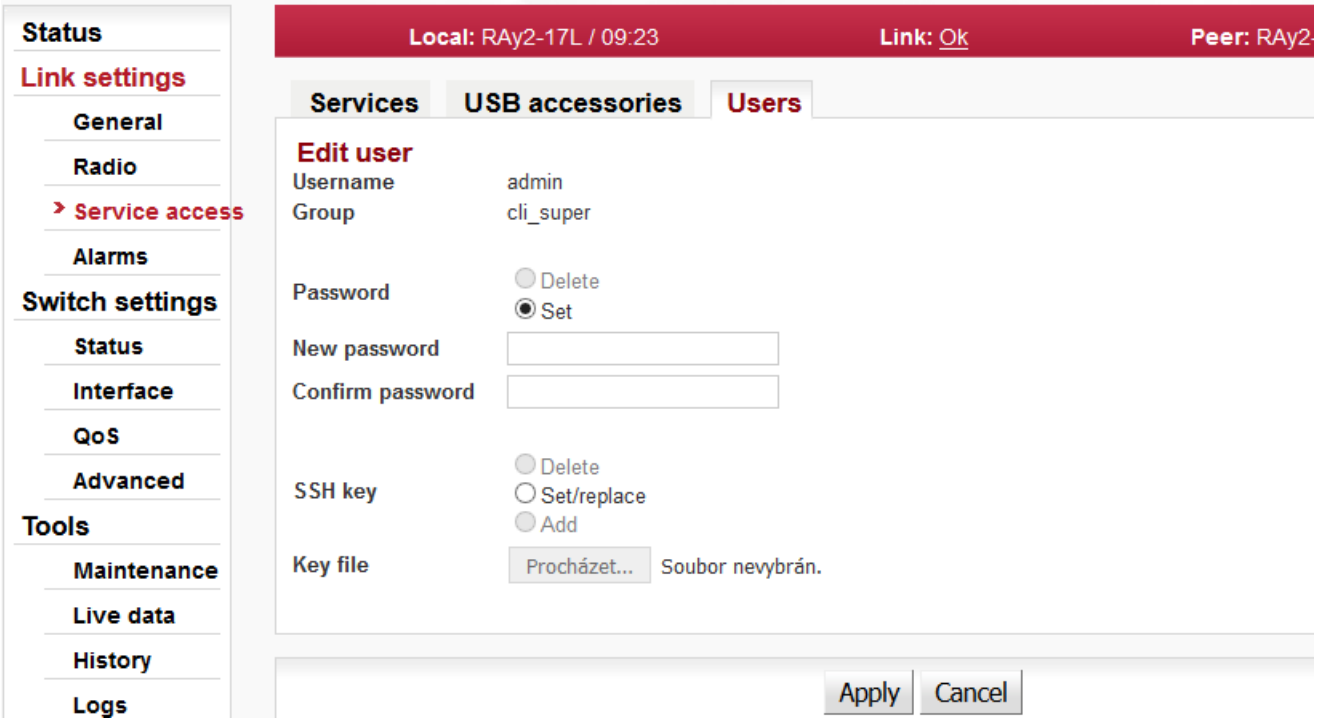


Fig. 7.12: Menu Link settings – Service access – Users – edit

Username	User name
Group	The group to which this user will belong.
Password	Password can be set or deleted. **Delete** – User will not have a password. The user will only be able to log in with an ssh key. In order to delete the password, you must first upload the ssh key. **Set** – Password settings.
New password	New password.
Confirm password	Repeat password.
SSH key	Working with ssh key. **Delete** – Clear all ssh keys from user account. **Set/replace** – Add a new key. If there already was any key(s), it will be overwritten. **Add** – Add a new key. You can enter multiple ssh keys in this way.
Key file	Insert key file.

Save the menu content by clicking on the button *Apply*.

Backup user

The user settings can be backed up, see *Tools / Maintenance / Backup*.

Delete user

Users at level *cli_super* have a Delete button next to each user. Delete a user using this button without being asked to confirm deletion. Users at level *cli_super* cannot both be deleted.

Add user

The button is located on the bottom bar.

For level *cli_super* users, the *Add user* button is active. Use it to create a new user within any group.

Username	Name of new user.
Group	The group to which this user is assigned.
New password	Password for this user.
Confirm password	Repeat password.
SSH key	If you want the user to have access using ssh protocol and identity verification using ssh key, enter the ssh key here.

Create a new user account by clicking on the button *Apply*.

Mirror users

The button is located on the bottom bar.

For level *cli_super* users, the *Mirror users* button is active. This function will copy all user accounts from Local unit to Peer unit. All existing user accounts on the Peer unit are deleted.

7.4.4. Alarms

Alarms Config

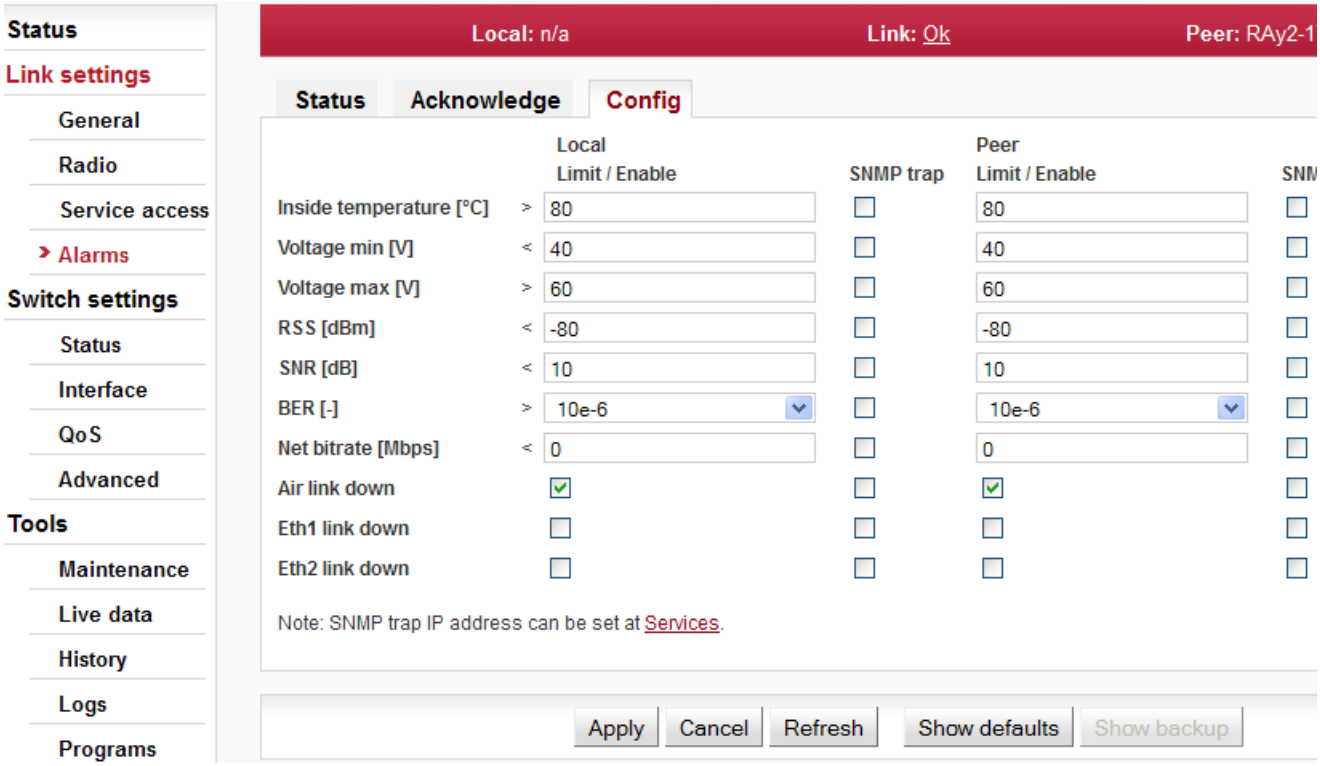


Fig. 7.13: Menu Link settings – Alarms – Config

The diagnostic system of the link monitors the operation of the unit.

It generates various output of events - system warnings and alarms. The event is always written to the system log and indicated in the status bar and Alarms-Status screen. Some events have adjustable thresholds. Events with no adjustable thresholds may or may not be Enabled. If they are not Enabled, the system event is not activated even if the system status is changed.

If the event goes above or below the set parameter limits or a link goes down or up, you can choose to send an SNMP trap.

alarm	default	description
Inside temper. [°C]	**>80**	Temperature inside the unit (on the modem board.)
Voltage min [V]	**<40**	Lower threshold of supply voltage.
Voltage max [V]	**>60**	Upper threshold of supply voltage. There is the same SNMP trap (same OID) both for Voltage min and max.
RSS [dBm]	**<−80**	Received Signal Strength.
SNR [dB]	**<10**	Signal to Noise Ratio.
BER [-]	**>10e^{-6}**	Bit Error Rate registered at the receiving end; instantaneous value.
Net bitrate [Mbps]	**0**	The system warning is generated when the current transfer capacity of radio channel is lower than the threshold set in this parameter.
Air link down	**ticked**	Interruption of radio link.

Eth link down	Corresponding user Eth link (Eth1/Eth2) on station interrupted. NOTE: The *EthX link* system alarm can only be activated if this alarm is Enabled. When the alarm is not Enabled, the *EthX link* alarm on *Status* screen is always *OK* regardless of the current status of the Ethernet link.
RF power fail	Loss of transmit power (not applicable for RAy2-17 neither RAy2-24).

Alarms Status

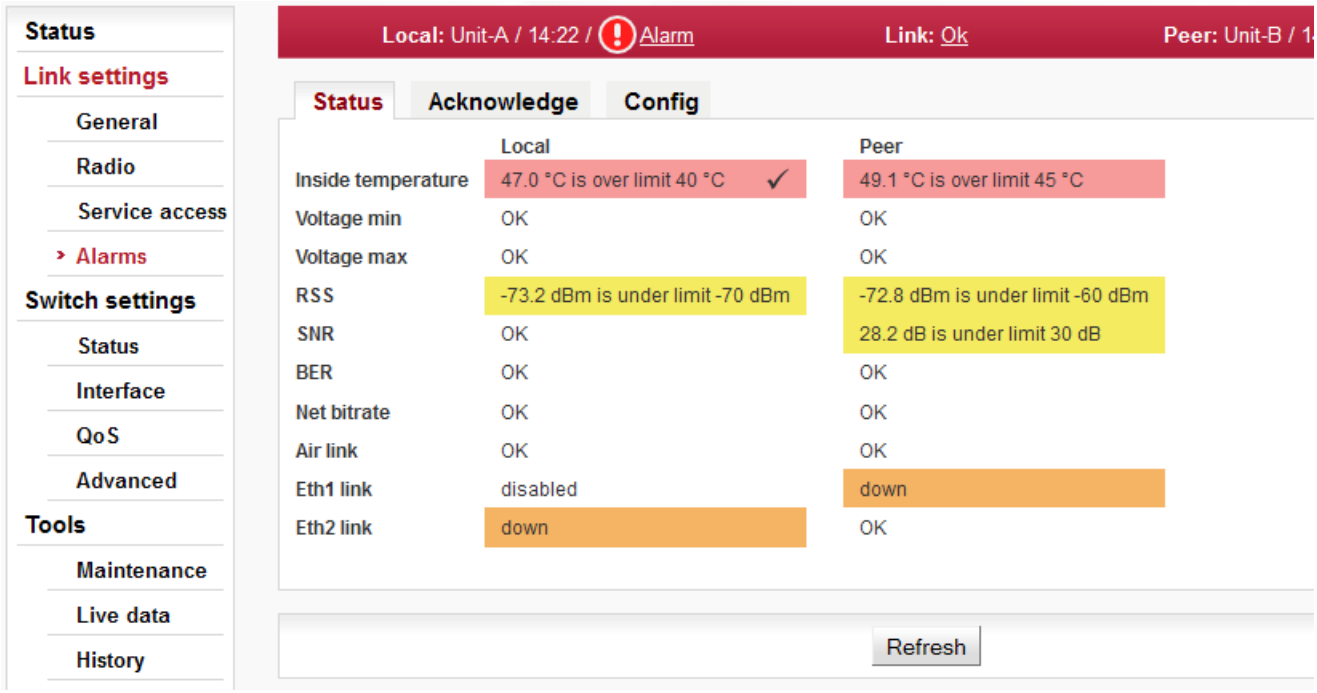


Fig. 7.14: Menu Link settings – Alarms – Status

Overview of alarms

All system alarms are listed on this screen. Inactive alarms are colored white with an "OK" text label. Active alarms are colored according to the severity of the alarm (see below) with a text message describing the measured value status.

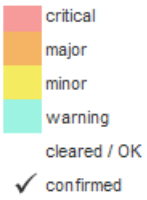


Fig. 7.15: Alarm severity scale

Alarms Acknowledge

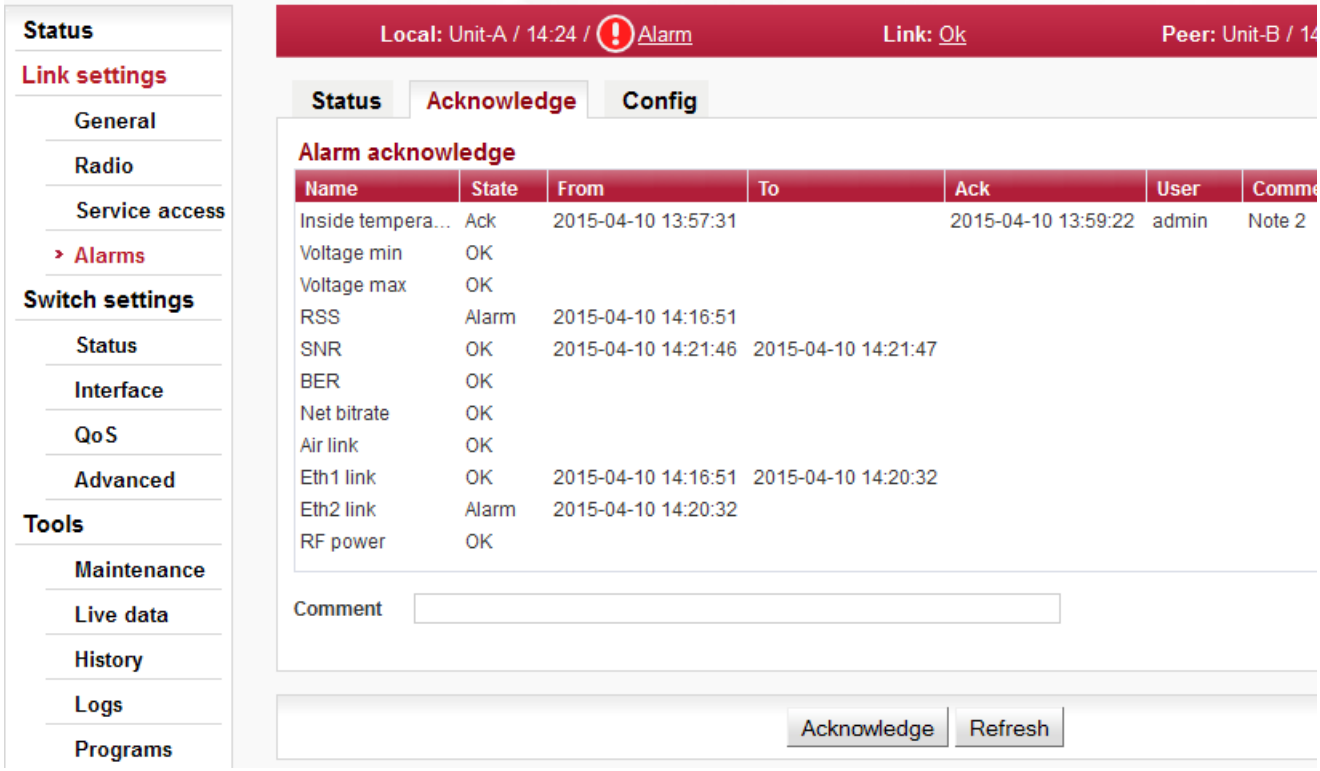


Fig. 7.16: Menu Link settings – Alarms – Acknowledge

Alarm acknowledgement is a way to allow the operator to confirm the system is in alarm state. Only an active alarm can be acknowledged.
Multiple selection of active alarms (to acknowledge groups of alarms) can be performed using Shift or Ctrl keys.

Name	Alarm identification. The following alarms can appear: Inside temperature, Voltage min, Voltage max, RSS, SNR, BER, Net bitrate, Air link, Eth1 link, Eth2 link, RF power
State	There are three possible alarm states: OK ... No alarm (alarm is inactive) or alarm disabled. Ack ... Alarm is active and acknowledged. Alarm ... Alarm is active and is not acknowledged.
From	Time stamp when the alarm occured.
To	Time stamp when the alarm expired (returned to normal conditions).
Ack	Time stamp when the alarm was acknowledged. Time stamp format: yyyy-MM-dd hh:mm:ss
User	Name (login) of the user who acknowledged the alarm.
Comment	The comment field can be used to add user defined comments when 'alarm acknowledge' is performed. Use this comment to describe important details of the alarm status. The comment can be up to 50 characters long. Special characters are not allowed. The alarm can be acknowledged multiple times with different comments. Every acknowledgement is written to the internal memory and is visible in the alarm log.

7.5. Switch settings

7.5.1. Status

Port status

The unit internal Ethernet switch port status

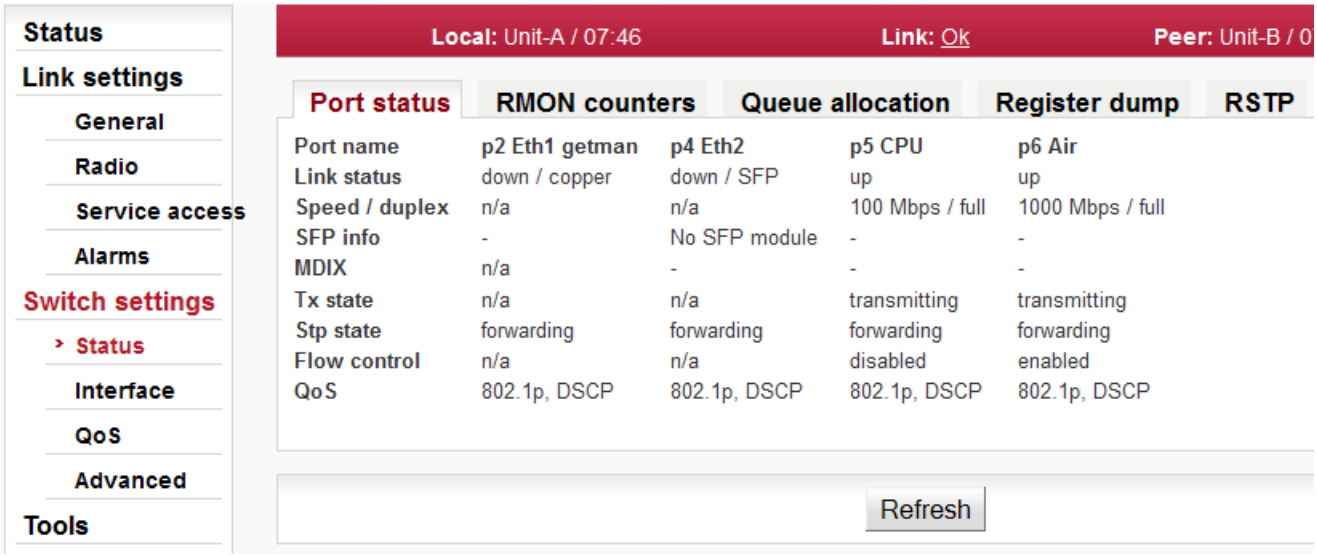


Fig. 7.17: Menu Switch settings - Port status

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Link status Ethernet link status can be

down / type	no link signal detected
up / type	link signal detected

The type of the physical layer is indicated after the slash

copper	metallic Ethernet interface
SFP	SFP module can be either optic or metallic

Speed / duplex Ethernet link Speed and duplex.

Speed:	10/100/1000 Mbps.
Duplex:	full/half

SFP info Information about the (optionally) inserted SFP module. The three different types of SFP modules can be used:

Fibre	dual mode with LC connector
Fibre	single mode with LC connector

Copper	with RJ45 connector

There can be one of the following scenarios:

scenario	message
SFP OK	The SFP vendor string read out of SFP module. The vendor, model, connector (RJ45/LC) and wavelength values are shown. Separate window with more detailed information can be opened by clicking the *more...* link.
No SFP	No SFP module
read error	n/a
no SFP option	–

MDIX Status of the internal crossover of Ethernet cables. (MDIX = internally crossed pairs, MDI = direct connection, N/A means an unknown state).

Tx state Port transmitting status can be

transmitting	Normal port operation
paused	Port transmitter is paused due to Pause frames reception

Flow control Mechanism for temporarily stopping the transmission of data on an Ethernet network. Enabling flow control allows use of buffers of connected active network elements for leveling uneven flow of user data. For correct operation it is necessary to also enable Flow control on the connected device. Flow control is handled by sending Pause frames to the connected device. See *Flow control* and *Pause limit* parameters.
Flow control can be one of the following values:

disabled	Flow control is disabled.
enabled	Flow control is enabled.
active	Flow control is enabled and activated. The port has requested the link partner not to send any more data (by sending Pause frames).

QoS Quality of Service status can be one of the following values:

disabled	QoS functions are disabled.
802.1p	QoS according to 802.1p is enabled.
DSCP	QoS according to DSCP is enabled.
802.1p,DSCP	QoS according to 802.1p and DSCP is enabled. The 802.1 prefer tag is selected.
DSCP,802.1p	QoS according to 802.1p and DSCP is enabled. The DSCP prefer tag is selected.

RMON counters

The unit internal Ethernet switch RMON counters

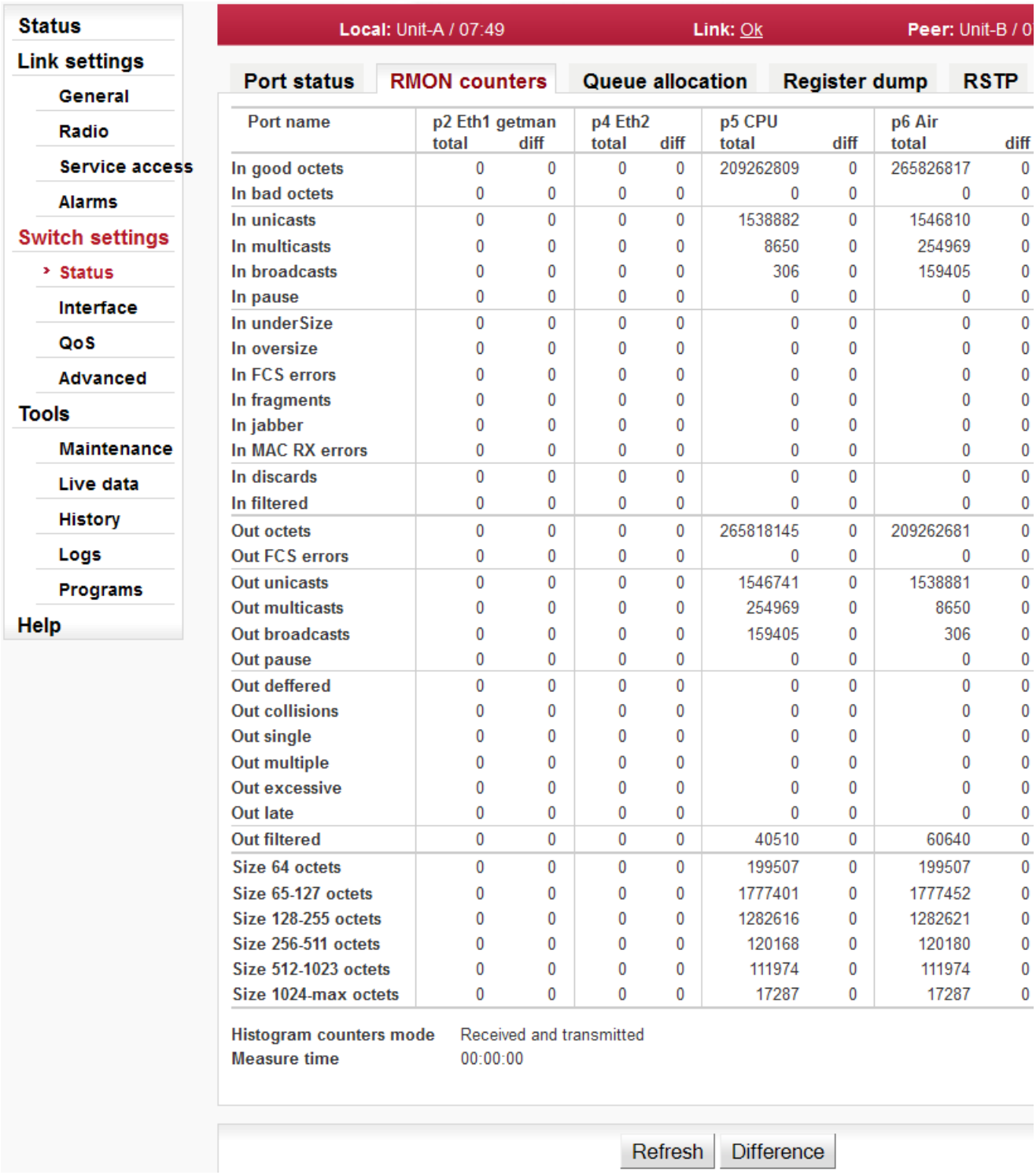


Fig. 7.18: Menu Switch settings - RMON counters

The Remote Network MONitoring (RMON) MIB was developed by the IETF to support monitoring and protocol analysis of LANs.

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

The Internal switch port RMON counters

These counters provide a set of Ethernet statistics for frames received on ingress and transmitted on egress.

Ingress statistics counters

In good octets	The sum of lengths of all good Ethernet frames received, that is frames that are not bad frames.
In bad octets	The sum of lengths of all bad Ethernet frames received.
In unicasts	The number of good frames received that have a Unicast destination MAC address.
In multicasts	The number of good frames received that have a Multicast destination MAC address. NOTE: This does not include frames counted in *In broadcasts* nor does it include frames counted in *In pause*.
In broadcasts	The number of good frames received that have a Broadcast destination MAC address.
In pause	The number of good frames received that have a Pause destination MAC address.
In undersize	Total frames received with a length of less than 64 octets but with a valid FCS.
In oversize	Total frames received with a length of more than MaxSize octets but with a valid FCS.
In FCS errors	Total frames received with a CRC error not counted in *In fragments*, *In jabber* or *In MAC RX errors*.
In fragments	Total frames received with a length of less than 64 octets and an invalid FCS.
In jabber	Total frames received with a length of more than MaxSize octets but with an invalid FCS.
In MAC RX errors	Total frames received with an RxErr signal from the PHY.
In discards	Total number of frames that normally would have been forwarded, but could not be due to a lack of buffer space.
In filtered	Total number of good frames that were filtered due to ingress switch policy rules.

Egress statistics counters

Out octets	The sum of lengths of all Ethernet frames sent from this MAC.

Out FCS errors	The number of frames transmitted with an invalid FCS. Whenever a frame is modified during transmission (e.g., to add or remove a tag) the frame's original FCS is inspected before a new FCS is added to a modified frame. If the original FCS is invalid, the new FCS is made invalid too and this counter is incremented.
Out unicasts	The number of frames sent that have a Unicast destination MAC address.
Out multicasts	The number of good frames sent that have a Multicast destination MAC address. NOTE: This does not include frames counted in *Out broadcasts* nor does it include frames counted in *Out pause*.
Out broadcasts	The number of good frames sent that have a Broadcast destination MAC address.
Out pause	The number of Flow Control frames sent.
Out deffered	The total number of successfully transmitted frames that experienced no collisions but are delayed because the medium was busy during the first attempt. This counter is applicable in half-duplex only.
Out collisions	The number of collision events seen by the MAC not including those counted in *Out Single, Multiple, Excessive*, or *Late*. This counter is applicable in half-duplex only. See Auto negotiation.
Out single	The total number of successfully transmitted frames that experienced exactly one collision. This counter is applicable in half-duplex only.
Out multiple	The total number of successfully transmitted frames that experienced more than one collision. This counter is applicable in half-duplex only.
Out excessive	The number frames dropped in the transmit MAC because the frame experienced 16 consecutive collisions. This counter is applicable in half-duplex only.
Out late	The number of times a collision is detected later than 512 bits-times into the transmission of a frame. This counter is applicable in half-duplex only.
Out filtered	Total number of good frames that were filtered due to egress switch policy rules.

Frame size histogram counters

Size 64 octets	Total frames received (and/or transmitted) with a length of exactly 64 octets, including those with errors.
Size 65-127 octets	Total frames received (and/or transmitted) with a length of between 65 and 127 octets inclusive, including those with errors.
Size 128-255 octets	Total frames received (and/or transmitted) with a length of between 128 and 255 octets inclusive, including those with errors.
Size 256-511 octets	Total frames received (and/or transmitted) with a length of between 256 and 511 octets inclusive, including those with errors.
Size 512-1023 octets	Total frames received (and/or transmitted) with a length of between 512 and 1023 octets inclusive, including those with errors.

Size 1024-max octets	Total frames received (and/or transmitted) with a length of between 1024 and MaxSize (see MTU parameter) octets inclusive, including those with errors.

Histogram counters mode

Frame size histogram counters can count received and/or transmitted octets. The mode of histogram counters is indicated here.

Measure time

This is the time interval, the *diff* column is valid for. The *diff* column shows the difference of the actual value of the counters at the moment of pressing the Difference button and the value of the counters at the moment of pressing the Refresh button.

Refresh Difference

In another way: The Difference counter reference value can be reset by pressing the Refresh button. The time point at which the Difference counter sample is triggered and the *diff* value is calculated is defined by pressing the Difference button.

The *total* column always shows the actual values. It is refreshed either by pressing the Refresh and also the Difference button.

Queue allocation

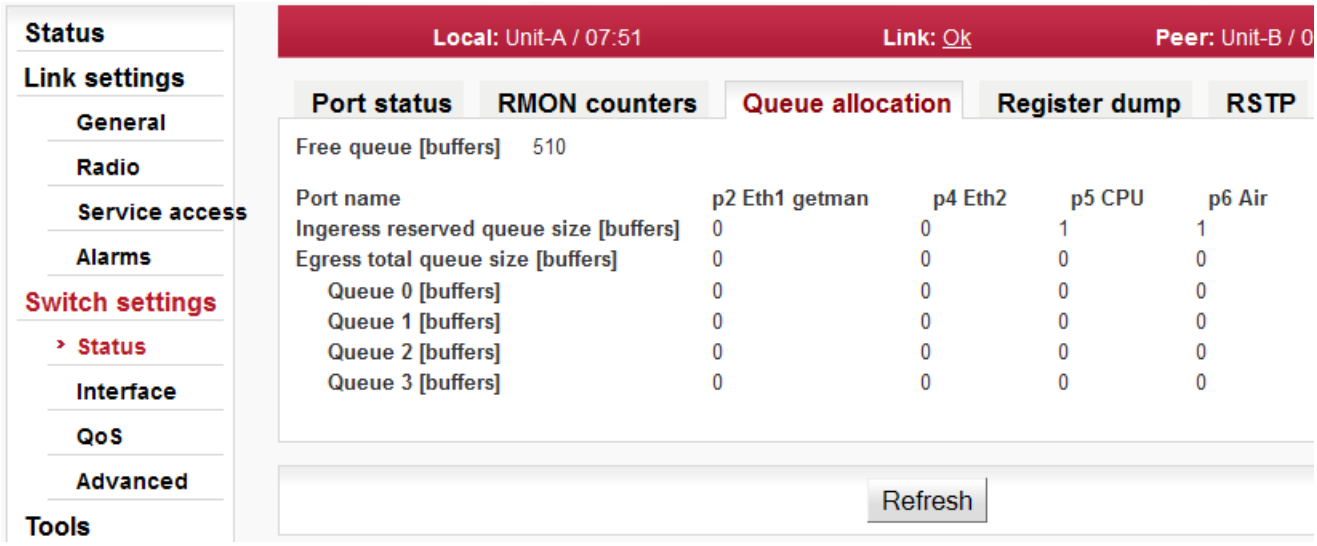


Fig. 7.19: Menu Switch settings - Queue allocation

Free queue Free Queue Size Counter. This counter reflects the current number of unallocated buffers available for all the ports [buffers].

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Ingress ... This counter reflects the current number of reserved Ingress buffers assigned to this port [buffers].

Egress ... This counter reflects the current number of Egress buffers switched to this port. This is the total number of buffers across all priority queues [buffers].

Queue 0~3 [buffers] Those counters reflect the current number of Egress buffers switched to this port for individual priority queues [buffer].

Register dump

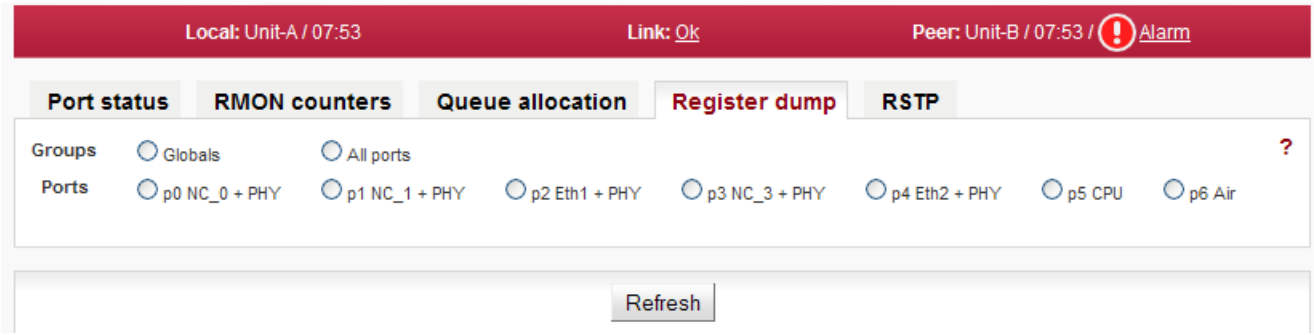


Fig. 7.20: Menu Switch settings - Register dump

The exact contents of the internal switch configuration and diagnostic registers can be listed for diagnostic purposes. All registers are separated into several groups.

Groups	Globals	Global switch parameters.
	All ports	Global port related parameters.
Ports	Port specific parameters.	
Registers	Registers contents is listed in hexadecimal notation.	

RSTP

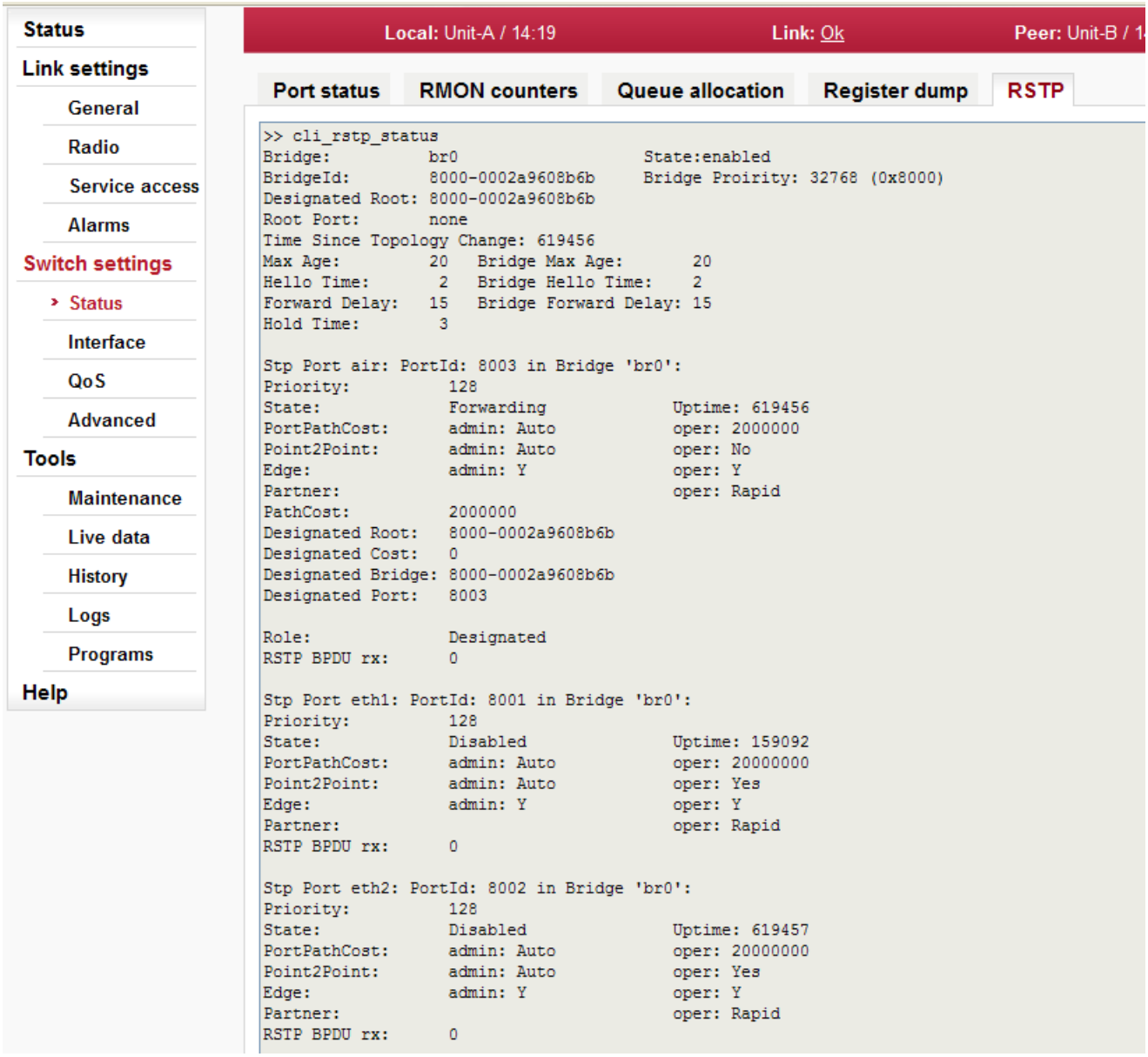


Fig. 7.21: Menu Switch settings - RSTP

RSTP service status

7.5.2. Interface

Port

Port settings

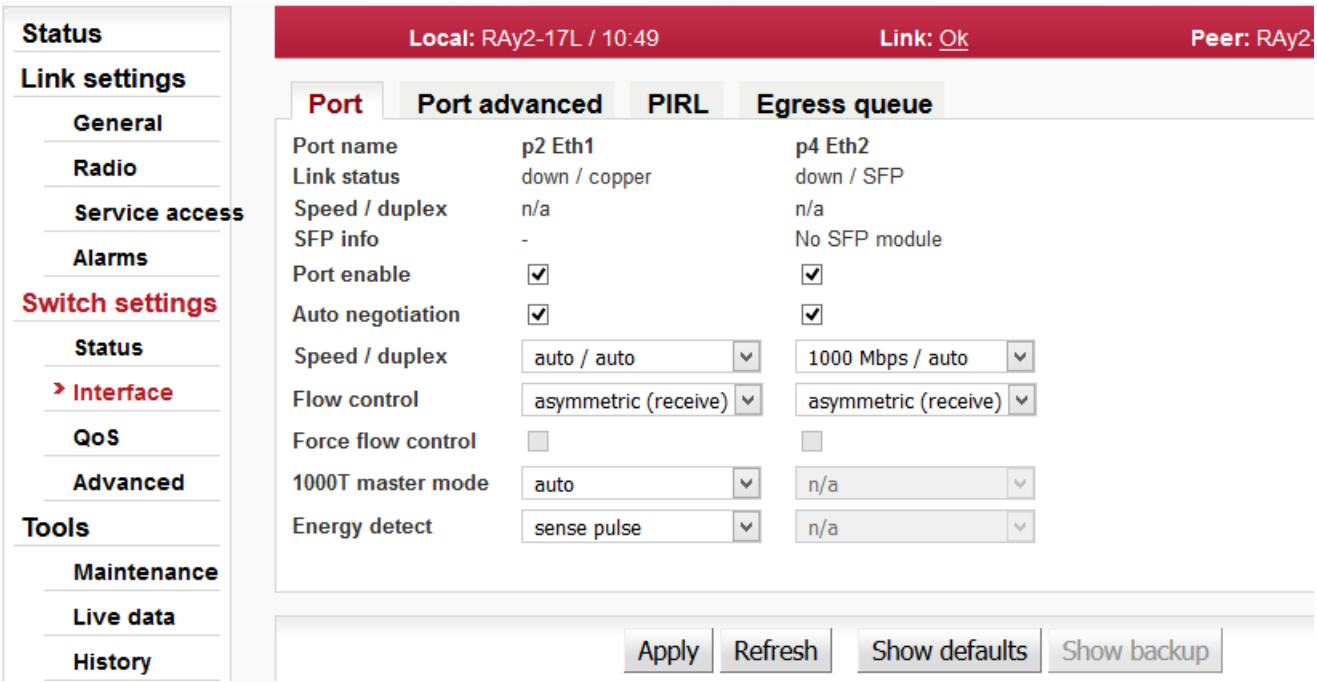


Fig. 7.22: Menu Switch settings - Port

Phyter is responsible for Ethernet signal conversion between wire (e.g. CAT7 cable) and internal switch bus.

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

- Eth1 The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
- Eth2 The external port (with SFP interface) labeled "ETH2". Port 4.

Link status Ethernet link status can be

- down / type no link signal detected
- up / type link signal detected

The type of the physical layer is indicated after the slash

- copper metallic Ethernet interface
- SFP SFP module can be either optic or metallic

Speed / duplex Ethernet link Speed and duplex.

- Speed 10/100/1000 Mbps
- Duplex full/half

SFP info Information about the (optionally) inserted SFP module. The three different types of SFP modules can be used:

- Fibre dual mode with LC connector

Fibre	single mode with LC connector
Copper	with RJ45 connector

There can be one of the following scenarios:

scenario	message
SFP OK	The SFP vendor string read out of SFP module. The vendor, model, connector (RJ45/LC) and wavelength values are shown. Separate window with more detailed information can be opened by clicking the *more...* link.
No SFP	No SFP module
read error	n/a
no SFP option	–

Port enable

The port can be enabled or disabled.

WARNING: When the port is disabled, no communication is possible through this port.

Auto negotiation

Auto-Negotiation is an Ethernet procedure by which two connected devices choose common transmission parameters, such as speed, duplex mode and flow control. In this process, the connected devices first share their capabilities regarding these parameters and then choose the highest performance transmission mode they both support.

The device supports three types of Auto-Negotiation:

10/100/1000BASE-T Copper Auto-Negotiation. (IEEE 802.3 Clauses 28 and 40)

1000BASE-X Fiber Auto-Negotiation (IEEE 802.3 Clause 37)

SGMII Auto-Negotiation (Cisco specification)

Auto-Negotiation provides a mechanism for transferring information from the local unit to the link partner to establish speed, duplex and Master/Slave preference during a link session.

Auto-Negotiation is initiated upon any of the following conditions:

Power up reset

Hardware reset

Software reset

Restart Auto-Negotiation

Transition from power down to power up

The link goes down

The **10/100/1000BASE-T Auto-Negotiation** is based on Clause 28 and 40 of the IEEE 802.3 specification. It is used to negotiate speed, duplex and flow control over CAT5 (or higher) UTP cable. Once Auto-Negotiation is initiated, the device determines whether or not the remote device has Auto-Negotiation capability. If so, the device and the remote device negotiate the speed and duplex with which to operate.

If the remote device does not have Auto-Negotiation capability, the device uses the parallel detect function to determine the speed of the remote device for 100BASE-TX and 10BASE-T modes. If a link is established based on the parallel

detect function, it is then required to establish the link at half-duplex mode only. Refer to IEEE 802.3 clauses 28 and 40 for a full description of Auto-Negotiation.

1000BASE-X Auto-Negotiation is defined in Clause 37 of the IEEE 802.3 specification. It is used to auto-negotiate duplex and flow control over fibre cable.

If the PHY enables 1000BASE-X Auto-Negotiation and the link partner does not, the link cannot linkup. The device implements an Auto-Negotiation bypass mode.

SGMII Auto-Negotiation. SGMII is a de-facto standard designed by Cisco. SGMII uses 1000BASE-X coding to send data as well as Auto-Negotiation information between the PHY and the MAC. However, the contents of the SGMII Auto-Negotiation are different than the 1000BASE-X Auto-Negotiation.

WARNING: If one device provides Auto-negotiation and the other works with a manual link parameters settings (i.e. without Auto-negotiation) the link operates in half-duplex mode. If the manual settings is set to full-duplex, the *Out collisions* may occur.

Speed / duplex

Ethernet link speed and duplex mode can be selected. Both parameters can be either auto negotiated or set manually. When the Auto negotiation parameter is disabled, only manual setting of the speed and duplex is possible. In most cases it is better to enable the auto negotiation and use "auto / auto" speed and duplex settings.

There are two possibilities to force the link to operate in specific speed and duplex:

Auto negotiation enabled. Select the desired Speed / duplex. The auto negotiation process advertises only this specified link mode. The link partner is asked to use it.

Auto negotiation disabled. Select the desired Speed / duplex. The link is set to this specified link mode. The link partner has to be set manually to the same mode.

Flow control

The flow control mechanism is handled by sending Pause frames to the connected device. There are several modes of Pause frames generation:

no pause	Pause frames disabled.
symmetric	Pause frames transmission and reception enabled.
asymmetric (send)	Pause frames transmission enabled, reception disabled.
asymmetric (receive)	Pause frames reception enabled, transmission disabled.

Auto-Negotiation has to be enabled to enable Pause frames sending and receiving.

Force flow control

If the Auto-Negotiation is disabled and Flow control is required, the Force flow control parameter can be used. Flow control is turned on without having to be Auto-Negotiated

1000T master mode

The 1000BASE-T master/slave mode can be manually configured.

auto	Automatic MASTER/SLAVE configuration.
master	Manual configure as MASTER.
slave	Manual configure as SLAVE.

Energy detect

The device can be placed in energy detect power down modes by selecting either of the two energy detect modes. Both modes enable the PHY to wake up on its

own by detecting activity on the Ethernet cable. The energy detect modes only apply to the copper media.

In the first *sense* mode, if the PHY detects energy on the line, it starts to Auto-Negotiate sending FLPs (Fast Link Pulse) for 5 seconds. If at the end of 5 seconds the Auto-Negotiation is not completed, then the PHY stops sending FLPs and goes back to monitoring received energy. If Auto-Negotiation is completed, then the PHY goes into normal 10/100/1000 Mbps operation. If during normal operation the link is lost, the PHY will re-start Auto-Negotiation. If no energy is detected after 5 seconds, the PHY goes back to monitoring received energy.

In *sense pulse* mode, the PHY sends out a single 10 Mbps NLP (Normal Link Pulse) every one second. Except for this difference, this is identical to the previous mode (*sense*) operation. If the device is in *sense* mode, it cannot wake up a connected device; therefore, the connected device must be transmitting NLPs. If the device is in *sense pulse* mode, then it can wake a connected device.

off	Off
sense pulse	Sense and periodically transmit NLP (Energy Detect+TM).
sense	Sense only on Receive (Energy Detect).

Port advanced

The unit internal Ethernet switch Port settings

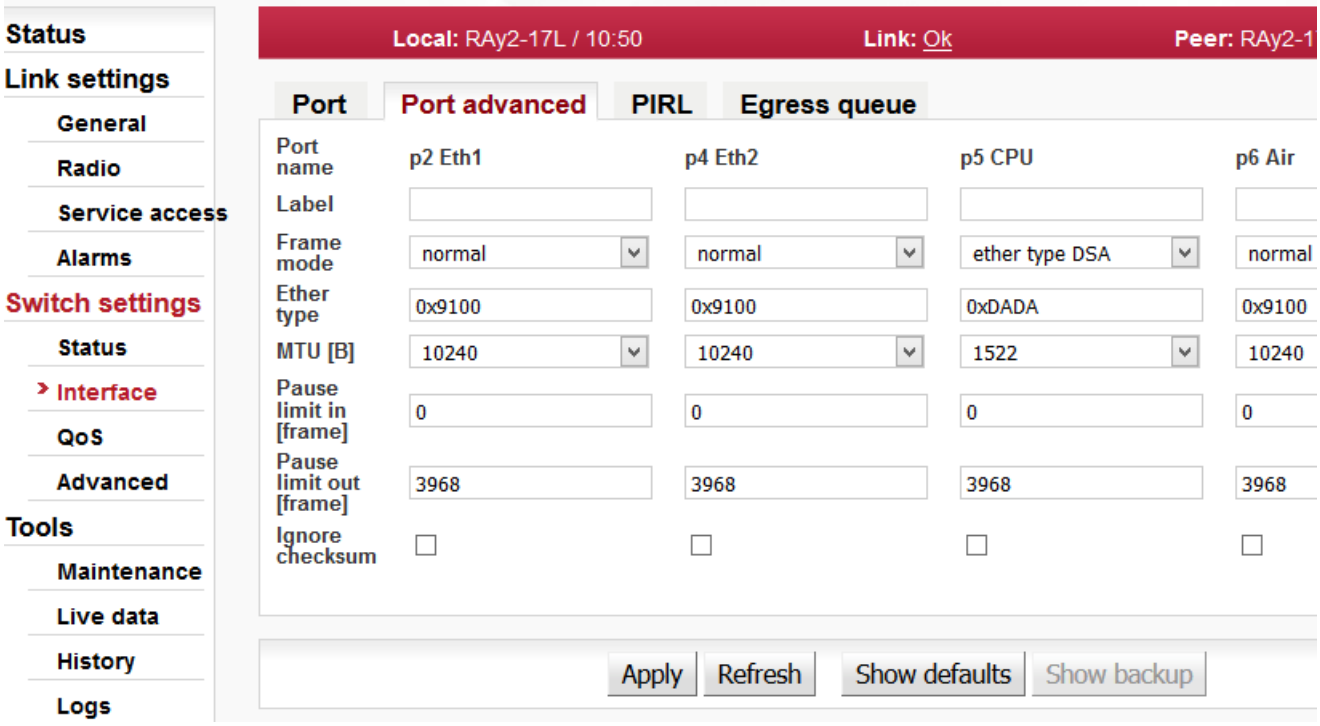


Fig. 7.23: Menu Switch settings - Port advanced

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

- Eth1 The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
- Eth2 The external port (with SFP interface) labeled "ETH2". Port 4.
- CPU The internal port to management CPU. It is physical port number 5.
- Air The internal port to radio modem, i.e. link to the peer unit. Port 6.

Label Custom port name.

Frame mode Ethernet Frame mode control defines the expected Ingress and the generated Egress tagging frame format for this port as follows:

- normal Normal Network mode uses industry standard IEEE 802.3ac Tagged or Untagged frames. Tagged frames use an Ether Type of 0x8100. Ports that are expected to be connected to standard Ethernet devices should use this mode.
- DSA Inactive options are not required.
- provider Provider mode uses user definable Ether Types per port (see Ether type parameter) to define that a frame is Provider Tagged. Ports that are connected to standard Provider network devices, or devices that use Tagged frames with an Ether Type other than 0x8100 should use this mode.

  Frames that ingress this port with an Ether Type that matches the port's *Ether Type* parameter will be considered tagged, will have the tag's VID and PRI bits assigned to the frame (i.e. they will be used for

switching and mapping), and will have the Provider Tag removed from the frame. If subsequent Provider Tags are found following the 1st Provider Tag, they too will be removed from the frame with their VID and PRI bits being ignored. Modified frames will be padded if required.

Frames that ingress this port with an Ether Type that does not match the *Ether Type* parameter will be considered untagged. The ingressing frames are modified so they are ready to egress out Customer ports (Normal Network Frame Mode ports) unmodified.

Frames that egress this port will always have a tag added (even if they were already tagged). The added tag will contain this port's *Ether Type* as its Ether Type. The PRI bits will be the Frame Priority FPri assigned to the frame during ingress. The VID bits will be the source port's Default VID bits (if the source port was in Normal Network mode), or the VID assigned to the frame during ingress (if the source port was in Provider mode).

ether type DSA

Valid only for the "p5 CPU" port.

Ether Type DSA mode uses standard Marvell DSA Tagged frame information following a user definable Ether Type (see Ether type parameter). This mode allows the mixture of Normal Network frames with DSA Tagged frames and is useful on ports that connect to a CPU.

Frames that ingress this port with an Ether Type that matches the port's "Ether Type" will be considered DSA Tagged and processed accordingly. The frame's Ether Type and DSA pad bytes will be removed so the resulting frame will be ready to egress out Marvell DSA Tag Mode ports unmodified. Frames that ingress this port with a different Ether Type will be considered Normal Network Frames and processed accordingly.

Marvell DSA Tag control frames that egress this port will always get the port's "Ether Type" inserted followed by two pad bytes of 0x00 before the DSA Tag. Marvell DSA Tag Forward frames that egress this port can egress just like the control frames (with the added Ether Type and pad) or they can egress as if the port was configured in Normal Network mode. This selection is controlled by the port's Egress Mode bits above.

Frame type

Ethernet frame type (often called EtherType) is used to indicate which protocol is encapsulated in the payload of an Ethernet Frame. This parameter is important when one protocol is encapsulated to another protocol.

Examples:

Eth. type	Standard	Comment
0x8100	IEEE 802.1q	Double-tagged, Q-in-Q or C-tag stacking on C-tag. C-tag in IEEE 802.1ad frames
0x88a8	IEEE 802.1ad	S-Tag
0x88e7	IEEE 802.1ah	S-Tag (backbone S-Tag)
0x9100	-	It is used very often. For example an old non-standard 802.1QinQ protocol uses this value.

See http://en.wikipedia.org/wiki/EtherType for futher details.

MTU [B]

MTU determines the maximum frame size allowed to be received or transmitted from or to a given physical port. This implies that a Jumbo frame may be allowed to be

received from a given input port but may or may not be allowed to be transmitted out of a port or ports. The possible values are 1522, 2048 and 10240 Bytes.

NOTE: The definition of frame size is counting the frame bytes from MAC_DA through Layer2 CRC of the frame.

Pause limit in [frame] Limit the number of continuous Pause refresh frames that can be received on this port (if full-duplex) or the number of 16 consecutive collisions (if half-duplex). When a port has flow control enabled, this parameter can be used to limit how long this port can be Paused or Back Pressured off to prevent a port stall through jamming.

The Flow Control on the port is (temporarily) disabled when the Pause refresh frames count exceeds the value of this parameter.

Setting this parameter to 0 will allow continuous jamming to be received on this port.

Pause limit out [frame] Limit the number of continuous Pause refresh frames that can be transmitted from this port – assuming each Pause refresh is for the maximum pause time of 65536 slot times. When full-duplex Flow Control is enabled on this port, this parameter is used to limit the number of Pause refresh frames that can be generated from this port to keep this port's link partner from sending any data.

Clearing this parameter to 0 will allow continuous Pause frame refreshes to egress this port as long as this port remains congested.

Setting this parameter to 1 will allow 1 Pause frame to egress from this port for each congestion situation.

Setting this parameter to 2 will allow up to 2 Pause frames to egress from this port for each congestion situation, etc.

Ignore Frame checksum Ignore Frame checksum (FCS) - or in other words - Force good FCS in the frame. When this parameter is not set (default behaviour), frames entering this port must have a good CRC or else they are discarded. When this parameter is set, the last four bytes of frames received on this port are overwritten with a good CRC and the frames are accepted by the switch (assuming that the frame's length is good and it has a destination).

PIRL

PIRL (Port based Ingress Rate Limiting) has the task of arranging the transfer of frames; ensuring as few frames as possible are discarded and that ports are not blocked.

Diagram of framework processing options are available within the QoS, PIRL and Egress queue control menus:

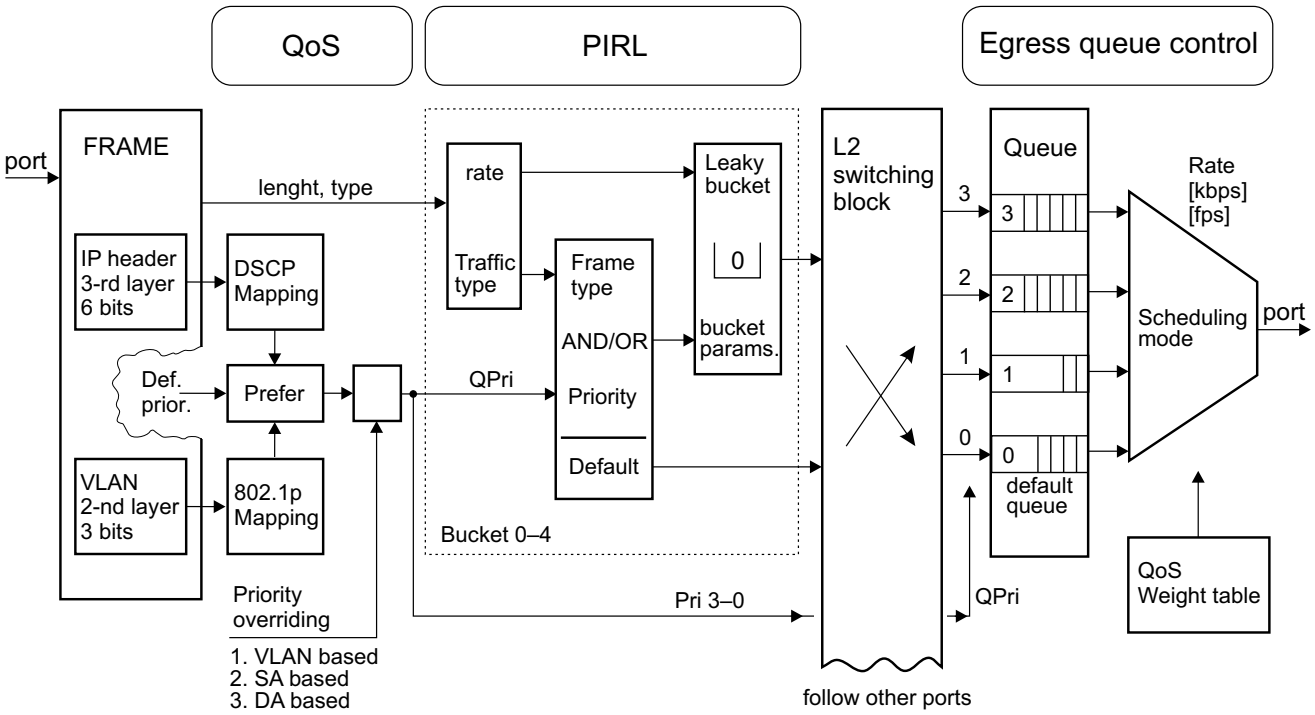


Fig. 7.24: PIRL and queues

Frame

The frame comes via port, has a certain length and MAC addresses SA and DA. The IP header carries the DSCP priority and may also carry the 802.1p VLAN priority.

QoS

The Queue priority (QPri) is created based on preferences within the DSCP or 802.1p priority. This priority takes values from 0 to 3, and controls the processing of frames inside the switch.

- Untagged frames are provided with 802.1p priority by default.
- Priorities may be remapped.
- The priority can also be overwritten by the Advanced menu priority derived from a VLAN, SA and/or DA addresses.

The Frame priority (FPri) is processed in a similar manner. Frame coming from the network and frame being sent to the network is marked by this priority.

PIRL

Between the port and the common switch there may be between 1 and 5 “flow restrictors” working in parallel according to the schedule “leaky bucket”. These are called “Resource”. This is analogous to

the container which is intermittently replenished by tokens according to incoming frames and is continuously emptied. Regulatory measures are implemented at a certain height to ensure the bucket does not overflow.

PIRL - Edit section of this menu is made up of several groups of parameters:

- Resource identification.
- Resource capacity, transfer byte into tokens.
- Method of counting frames.
- Regulatory interventions (drop frame - reduce feeding)
- Selecting frames (all - by priority QPri - by type).

The above mentioned parameters are used to allocate part of a frame to each Resource. Their passage is regulated thus avoiding network congestion. If there is a framework that does not match the filter of any Resource, this then passes to the switch without restrictions.

Switching block

In this block (L2-switch) each frame is routed to a designated port according to the Advanced menu.

Egress queue

Block output queues. Each port receives frames from the L2 switch through 4 queues (No. 3-0). The highest priority has a queue No. 3. The frames are organized into queues according to their priorities QPri.

The Method to empty queues is selected by the parameter Scheduling Mode. The emptying rate is governed by the Rate limit parameter.

A Frame sent from the port to the network can be identified by priority FPri, although it is also possible to change its tag: see menu VLAN - Egress mode.

Port based ingress rate limiting, see also the Functional diagram

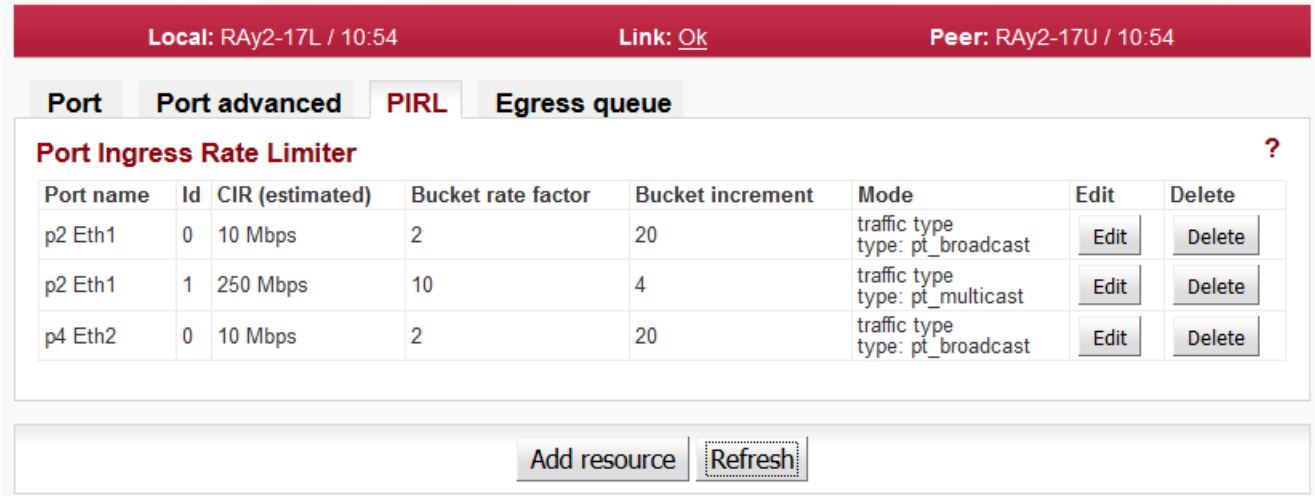


Fig. 7.25: Menu Switch settings - PIRL

The device supports per port TCP/IP ingress rate limiting along with independent Storm prevention. Port based ingress rate limiting accommodates information rates from 64 Kbps to 1 Mbps in increments of 64 Kbps, from 1 Mbps to 100 Mbps in increments of 1 Mbps and from 100 Mbps to 1000 Mbps in increments of 10 Mbps.

In addition to this, the device supports Priority based ingress rate limiting. A given ingress rate resource can be configured to track any of the four priority traffic types. One of the popular schemes for implementing rate limiting is a leaky bucket. The way a leaky bucket scheme works is that the bucket drains tokens constantly at a rate called Committed Information Rate (CIR) and the bucket gets replenished with tokens whenever a frame is allowed to go through the bucket. All calculations for this bucket are done in tokens. Therefore, both bucket decrementing and incrementing is performed using tokens (i.e., frame bytes are converted into bucket tokens for calculation purposes).

The device supports a color blind leaky bucket scheme.

The traffic below Committed Burst Size limit (CBS Limit) is passed without any further actions. If the traffic burst were to continue and the bucket token depth approaches closer to the Excess Burst Size limit (EBS Limit) by less than the CBS Limit, then a set of actions are specified. Note that if the frame gets discarded then the equivalent number of tokens for that frame will not get added to the bucket.

There are the two default ingress limiting rules already configured in the switch default configuration. They limit the maximum allowed ARP traffic comming to the CPU port to 10Mbps from Eth1 and 10Mbps from Eth2 ports.

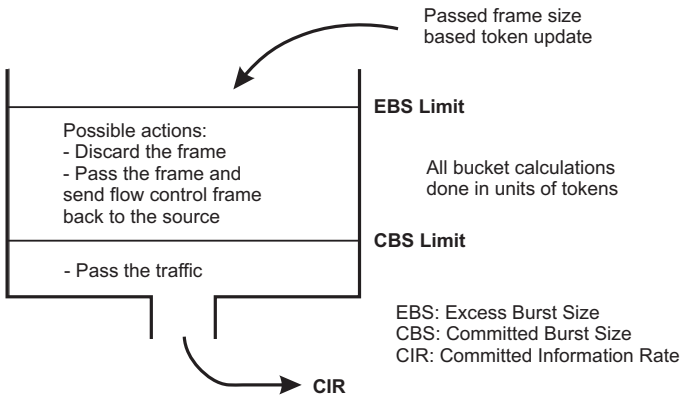


Fig. 7.26: Leaky bucket

Primary key	The live data icon indicates which parameter field is taken as the unique identifier in the database. This field entry ensures each record is unique and must not be duplicated.
Port name	Ports Eth1, Eth2, CPU, Air. See Port status.
Id	Each port can be assigned up to five different ingress rate resources. Each resource defines a rule (filter) for the incoming frame. If the rule is met, the frame is affected (as set by the EBS limit action parameter). If the incoming frame doesn't meet any rule, it is not affected by PIRL. The frame is accepted and forwarded further to the switch engine.
CIR (estimated)	The Committed Information Rate (CIR) is dependent on the Bucket Rate factor and the Bucket increment. The calculation is estimated as the real data throughput depends on frame size. The Accounted bytes parameter affects this as well. The formula for the CIR (in bits per second) is as follows: CIR = a * BRF / BI. Where "a" is constant, which is 12 500 000 for Accounted bytes="frame", and is 100 000 000 for Accounted bytes="layer1". BRF is Bucket Rate factor and BI is Bucket increment.
Bucket rate factor	This is a factor which determines the amount of tokens that need to be decremented for each rate resource decrement (which is done periodically based on the Committed Information Rate).
Bucket increment	Bucket increment (BI) indicates the amount of tokens that need to be added for each byte of the incoming frame.
Mode	Rate type or Traffic type of rate limiting. See Bucket type parameter.
Edit	Press Edit to edit selected PIRL resource.
Delete	Press Delete to delete selected PIRL resource.
Add resource	Press Add resource button to add another PIRL resource.

PIRL - resource configuration

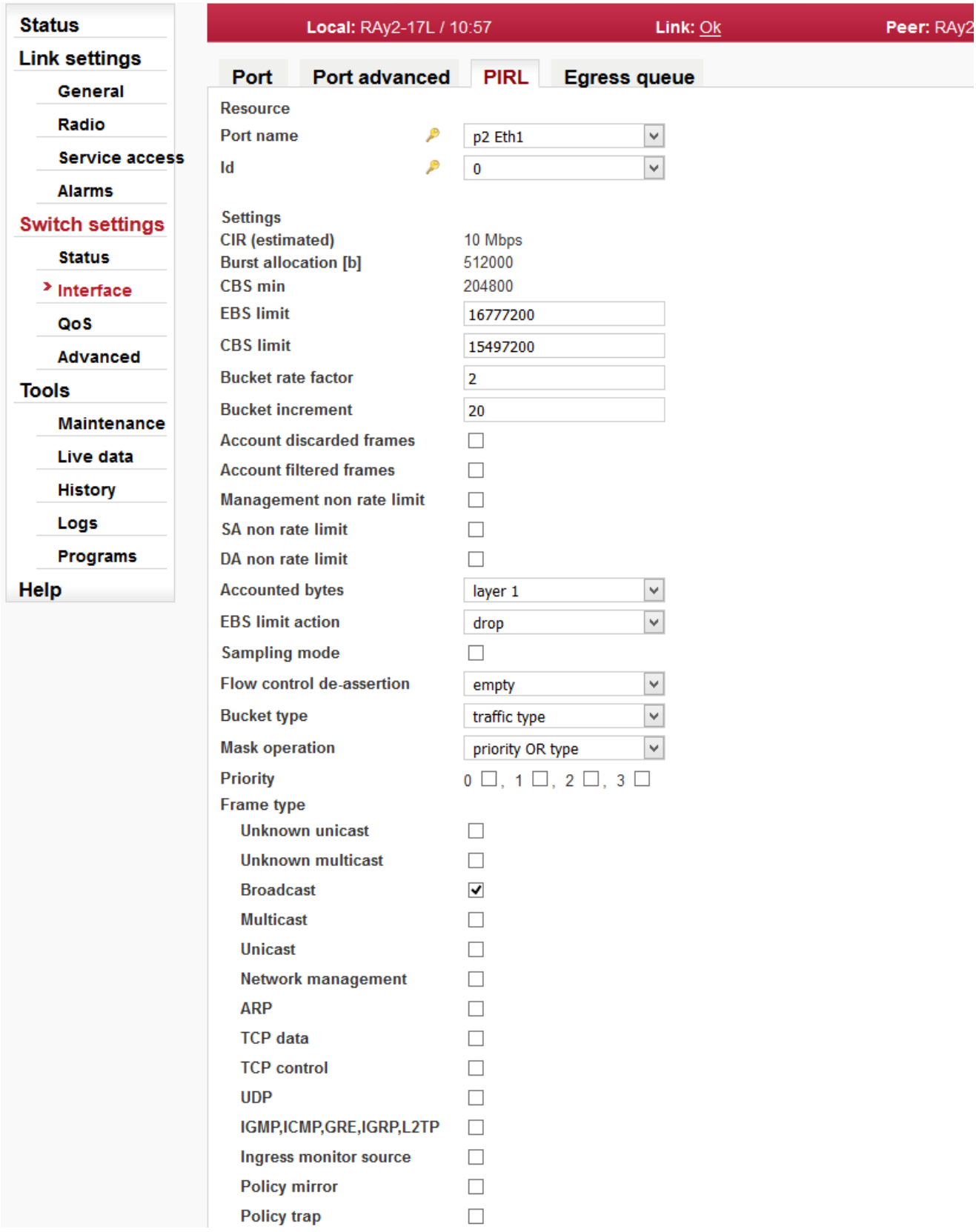


Fig. 7.27: Menu Switch settings - PIRL Resource

Each port can be assigned up to five different ingress rate resources.

Each resource defines a rule (filter) for the incoming frame. If the rule is met, the frame is affected (as set by the EBS limit action parameter). If the incoming frame doesn't meet any rule, it is not affected by PIRL. The frame is accepted and forwarded further to the switch engine.

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

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Each resource defines a rule (filter) for the incoming frame. If the rule is met, the frame is affected (as set by the EBS limit action parameter). If the incoming frame doesn't meet any rule, it is not affected by PIRL. The frame is accepted and forwarded further to the switch engine.

CIR (estimated) The Committed Information Rate (CIR) is dependent on the Bucket Rate factor and the Bucket increment.

The calculation is estimated as the real data throughput depends on frame size. The Accounted bytes parameter affects this as well.

The formula for the CIR (in bits per second) is as follows: CIR = a * BRF / BI.

Where "a" is constant, which is 12 500 000 for Accounted bytes="frame", and is 100 000 000 for Accounted bytes="layer1". BRF is Bucket Rate factor and BI is Bucket increment.

Burst allocation [b] The Burst allocation (BA) is dependent of the Bucket increment, the Committed Burst Size limit and the Excess Burst Size limit.

The formula for the BA is as follows: BA = 8 * (EBS-CBS) / BI.

Where EBS is the Excess Burst Size limit, CBS is the Committed Burst Size limit and BI is the Bucket increment.

The Burst allocation size should be less than switch internal memory which is 1Mb.

CBS min The minimum value for the CBS limit is related to the maximum frame size and Bucket increment.

The CBS limit should always be bigger than the CBS min.

The calculation for CBS min is as follows:

CBS min = BI * MaxFrameSize [bytes].

Where BI is the Bucket increment.

If the CBS limit is lower than this value (i.e. to allow a large burst), then an ingress stream composed of maximum sized frames may exceed the Committed Information Rate. It is for this reason that we recommend the CBS limit value always stays above the CBS min value. Also, the CBS limit should never exceed the EBS limit.

EBS limit Excess Burst Size limit.

The EBS limit should always be bigger than CBS limit. It is recommended that the EBS limit be set to 16777200.

CBS limit Committed Burst Size limit. This indicates the committed information burst amount.

Bucket rate factor This is a factor which determines the amount of tokens that need to be decremented for each rate resource decrement (which is done periodically based on the Committed Information Rate).

Bucket increment Bucket increment (BI) indicates the amount of tokens that need to be added for each byte of the incoming frame.

Account discarded frames This parameter decides whether the ingress rate limiting logic accounts for frames that have been discarded by the queue controller due to output port queue congestion reasons. To account for all frames coming into a given port associated with this rate resource, this parameter needs to be set.

Account filtered frames This parameter decides whether the ingress rate limiting logic accounts for frames that have been discarded because of ingress policy violations. To account for all frames coming into a given port associated with this rate resource, this parameter needs to be set.

Management non rate limit When this parameter is disabled all frames that are classified by the ingress frame classifier as MGMT frames would be considered to be ingress rate limited as far as this particular ingress rate resource is concerned.
When this parameter is enabled, all frames that are classified as MGMT frames by the ingress frame classifier would be excluded from the ingress rate limiting calculations for this particular ingress rate resource.

SA non rate limit When this parameter is enabled then SA ATU non rate limiting overrides can occur on this port. An SA ATU non rate limiting override occurs when the source address of a frame results in an ATU hit where the SA's MAC address returns an "Entry state" with "static non rate limiting" value. When this occurs the frame will not be ingress rate limited.

DA non rate limit When this parameter is enabled then DA ATU non rate limiting overrides can occur on this port. A DA ATU non rate limiting override occurs when the destination address of a frame results in an ATU hit where the DA's MAC address returns an "Entry state" with "static non rate limiting" value. When this occurs the frame will not be ingress rate limited.

Accounted bytes This parameter determines which frame bytes are to be accounted for in the rate resource's rate limiting calculations.

There are for different supported configurations:

frame	Frame based configures the rate limiting resource to account for the number of frames from a given port mapped to this rate resource.
layer 1	Preamble (8bytes) + Frame’s DA to CRC + IFG (inter frame gap, 12 bytes)
layer 2	Frame’s DA to CRC
layer 3	Frame’s DA to CRC - 18 - 4(if the frame is tagged)

A frame is considered tagged if it is either Customer of Provider tagged during ingress.

EBS limit action This parameter controls what kind of action is performed when the EBS limit has been exceeded. Three types of action can be selected:

drop	The frame that was received on the port will get discarded.

flow control — In this mode an Ethernet flow control frame gets generated (if the flow control is enabled for that port) and sent to the source port but the incoming frame gets passed through the rate resource. If the port is operating in half-duplex mode then the port gets jammed.

accept — The frame that was received on the port is accepted even though there are not enough tokens to accept the entire incoming frame. This mode is expected to be selected for TCP based applications. It is not recommended for media streaming applications where data timing is critical.

Flow control mode is expected to be programmed on ports that have a trusted flow control mechanism available. The EBS limit action is a per-port characteristic. If a port has multiple rate resource buckets then all buckets enabled are expected to be programmed with the same EBS limit action.

Sampling mode

This mode is used for sampling one out of so many frames/bytes that are being monitored. The stream could be identified by the ingress engine as a Policy mirror and packet sampling can be applied for that streeam using one of the rate resources.

In this mode, once the rate resource's "EBS Limit" is exceeded, the next incoming frame from this port that is assigned to this resource gets sent out to the mirror destination. After sending a sample frame, the token count within the rate resource is reset to zero and the bucket increments continue for each subsequent frame arrival.

The sampling mode is useful for limiting the number of Mirror frames sent to the mirror destination.

Flow control de-assertion

This parameter controls the flow control de-assertion when EBS limit action is set to generate a flow control message. There are two modes available:

empty — Flow control gets de-asserted only when the ingress rate resource has become empty.

CBS limit — Flow control gets de-asserted when the ingress rate resource has enough room to accept at least one frame of size specified by the CBS limit.
For example, if the CBS limit is programmed to be 2k Bytes, then the flow control will get de-asserted if there is at least 2k Bytes worth of tokens available in the ingress rate resource.

Bucket type

Any given bucket can be programmed to be aggregate rate based or traffic type based.

Rate based ingress rate limit: Limits all types of traffic on the ingress port.

Traffic type based ingress rate limit: Limits a specific type of traffic on the ingress port.

Mask operation

This parameter controls whether an ingress frame must meet both Priority and Frame type requirements to be counted for ingress rate calculations or if meeting only one requirement is sufficient to be counted for ingress rate calculations for this rate resource.

Priority

Any combinations of the four queue priorities can be selected. Frames with marked priority are accounted for in this ingress rate resource.

If there is no priority selected, priority of the frame doesn't have any affect on the ingress rate limiting calculations done for this ingress rate resource.

Frame type

Any of the following frame types can be selected to be tracked as part of the rate resource calculations:

Management (MGMT), Multicasts, Broadcasts, Unicasts, Address Resolution Protocol (ARP), TCP Data, TCP Ctrl, UDP, Non-TCPUDP (covers IGMP, ICMP, GRE, IGRP and L2TP), IMS, PolicyMirror, PolicyTrap, Unknown Unicasts or Unknown Multicasts.

More than one frame type can be selected for a given rate resource.

Egress queue control

See also Output queue diagram.

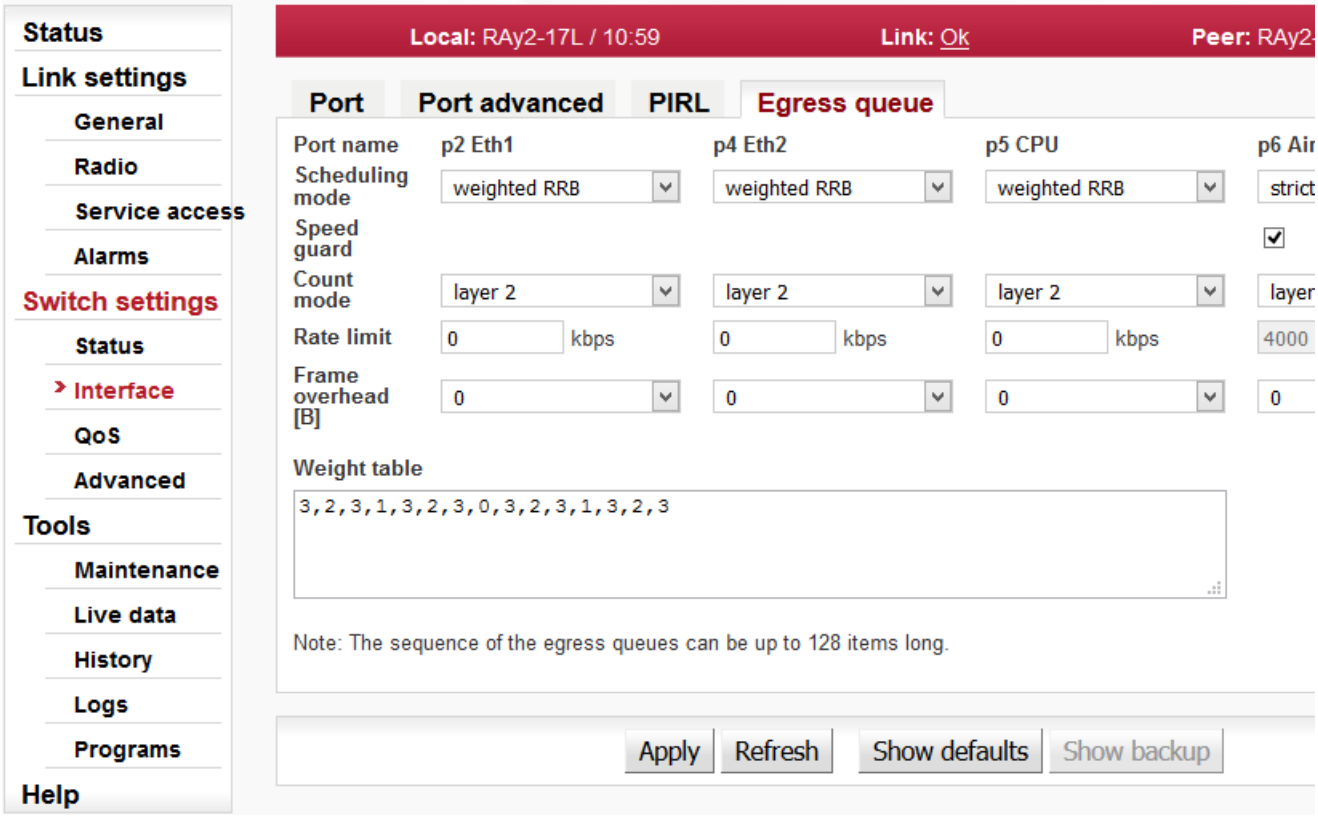


Fig. 7.28: Menu Switch settings - Egress queue

Port name

Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Scheduling mode

Port's Scheduling mode.

The device supports strict priority, weighted round robin, or a mixture on a per egress port selection basis.

In the strict priority scheme all top priority frames egress for a port until that priority's queue is empty, then the next lower priority queue's frames egress, etc. This approach can cause the lower priorities to be starved out preventing them from transmitting any frames but also ensures that all high priority frames egress the switch as soon as possible.

In the weighted scheme an 8, 4, 2, 1 weighting is applied to the four priorities unless an alternate weighting is programmed into the QoS Weights Table. This approach prevents the lower priority frames from being starved out with only a slight delay to the higher priority frames.

Some applications may require the top priority queue, or the top two priority queues to be in a fixed priority mode while the lower queues work in the weighted approach. All scheduling modes are selectable on a per port basis.

The port scheduling mode can be one of the following values:

weighted RRB	Use a weighted round robin queuing scheme.
strict pri 3	Use Strict for priority 3 and use weighted round robin for priorities 2,1 and 0
strict pri 3, 2	Use Strict for priorities 3 and 2 and use weighted round robin for priorities 1 and 0
strict	Use a Strict priority scheme for all priorities

Speed guard

The speed guard controls automatically the Egress data rate shaping according to available capacity of the Air channel. The Air channel capacity check and the Egress shaping adjustment takes place approx. once per 50 ms.

Count mode

Egress rate limiting count mode. This parameter is used to control which bytes in the transmitted frames are counted for egress rate limiting as follows:

frame	The egress rate limiting is done based on frame count [fps] as opposed to the byte count [kbps] of the packet.
layer 1	Preamble (8bytes) + Frame's DA to CRC + IFG (inter frame gap, 12 bytes)
layer 2	Frame's DA to CRC
layer 3	Frame's DA to CRC - 18 - 4(if the frame is tagged)

Only one tag is counted even if the frame contains more than one tag. A frame is considered tagged if the egress frame going out onto the wire is tagged.

Rate [kbps] / [fps]

Egress data rate shaping. When Rate = 0 egress rate limiting is disabled.

NOTE: The Count mode parameter is used to control which bytes in the transmitted frames are counted for egress rate limiting.

If the egress shaping is controlled by frame rate, the desired frame rate can vary from 7.6k to 1.488M frames per second. Valid values are between 7600 and 1488000.

If the egress shaping is controlled by bit rate, the desired rate can vary from 64 kbps to 1 Gbps in the following increments:

Desired rate between 64 kbps and 1 Mbps in increments of 64 kbps

Desired rate between 1 Mbps to 100 Mbps in increments of 1 Mbps

Desired rate between 100 Mbps to 1 Gbps in increments of 10 Mbps

Therefore, the valid values are:

64, 128, 192, 256, 320, 384,..., 960,

1000, 2000, 3000, 4000, ..., 100000,

110000, 120000, 130000, ..., 1000000

Frame overhead [B]

Egress Rate Frame Overhead adjustment.

This parameter is used to adjust the number of bytes that need to be added to a frame's IFG (inter frame gap) on a per frame basis. This is to compensate for a protocol mismatch between the sending and the receiving stations. For example if the receiving station were to add more encapsulations to the frame for the nodes

further down stream, this per frame adjustment would help reduce the congestion in the receiving station.

This adjustment, if enabled, is added to the Egress Rate Control's calculated transmitted byte count meaning Egress Rate Control must be enabled for this Frame Overhead adjustment to work.

Weight table The weighted round robin alternate weighting can be defined here. The sequence of the output queue numbers (0,1, 2 or 3) defines the sequence of the output queue frame egressing. This sequence can be up to 128 items long.

7.5.3. QoS

The QoS classification is handled in the switch Ingress block. The Ingress block does not perform the QoS switching policy, which is the task of the Queue Controller.

See the Functional diagram.

802.1p

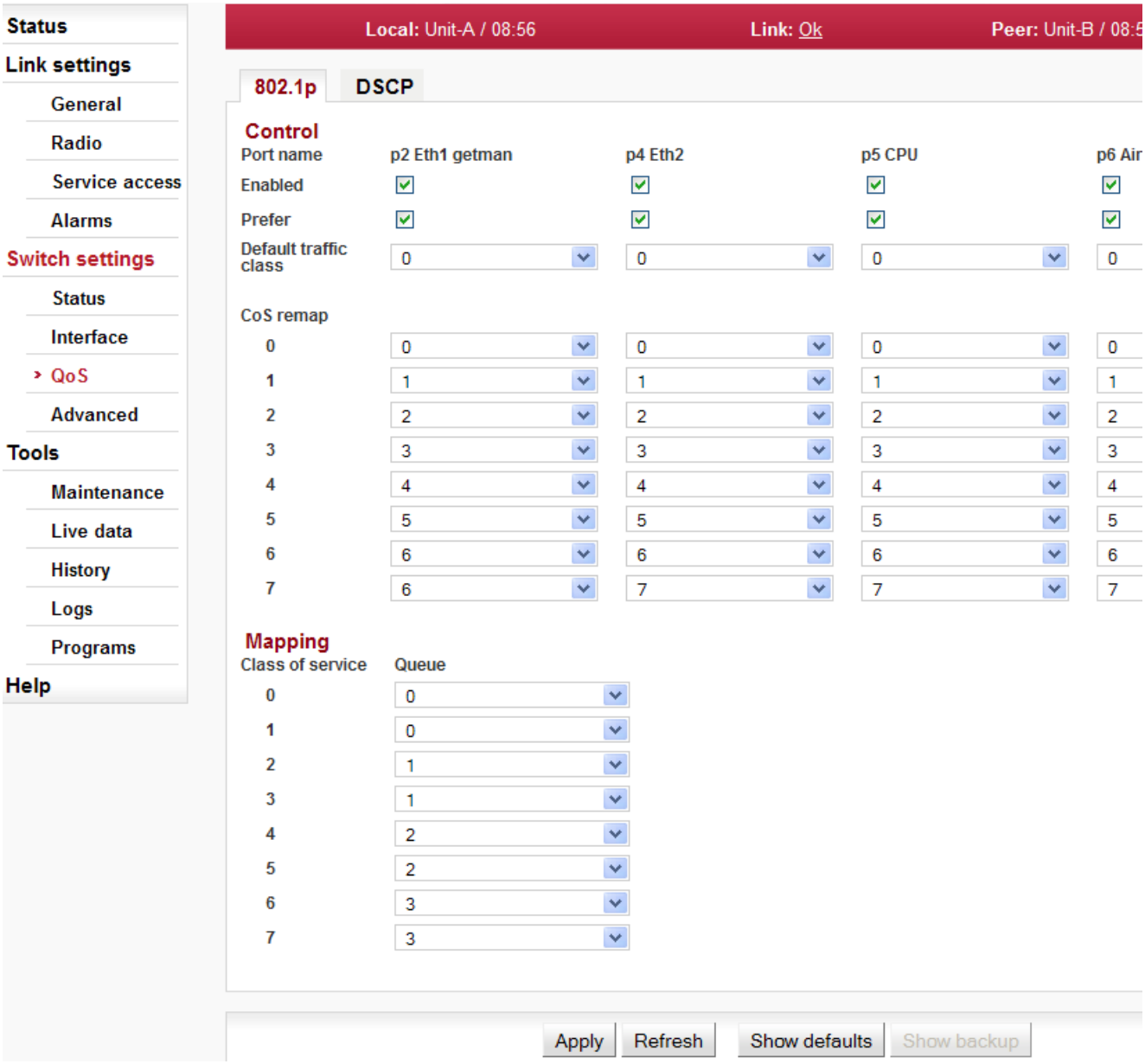


Fig. 7.29: Menu Switch settings - 802.1p

The IEEE 802.1p QoS technique also known as class of service (CoS), is a 3-bit field called the Priority Code Point (PCP) within an Ethernet frame header when using VLAN tagged frames as defined by IEEE 802.1Q. It specifies a priority value of between 0 and 7 inclusive that can be used by QoS disciplines to differentiate traffic. The value 0 is generally taken as the lowest priority and 7 as the highest priority.

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Enabled The QoS classification according to IEEE 802.1p priority bits is enabled/disabled.

Prefer Enable this parameter to force 802.p priority over DSCP.

When enabled, the DSCP Prefer parameter is automatically disabled.

Default traffic class The IEEE 802.1q untagged frames (thus having no IEEE 802.1p priority) are treated with this priority.

CoS remap The frame's IEEE 802.1p priority can be changed to other value.

Class of service Arranging individual priorities (coded in priority bits according to IEEE 802.1p) into selected output queue (0..3).

DSCP

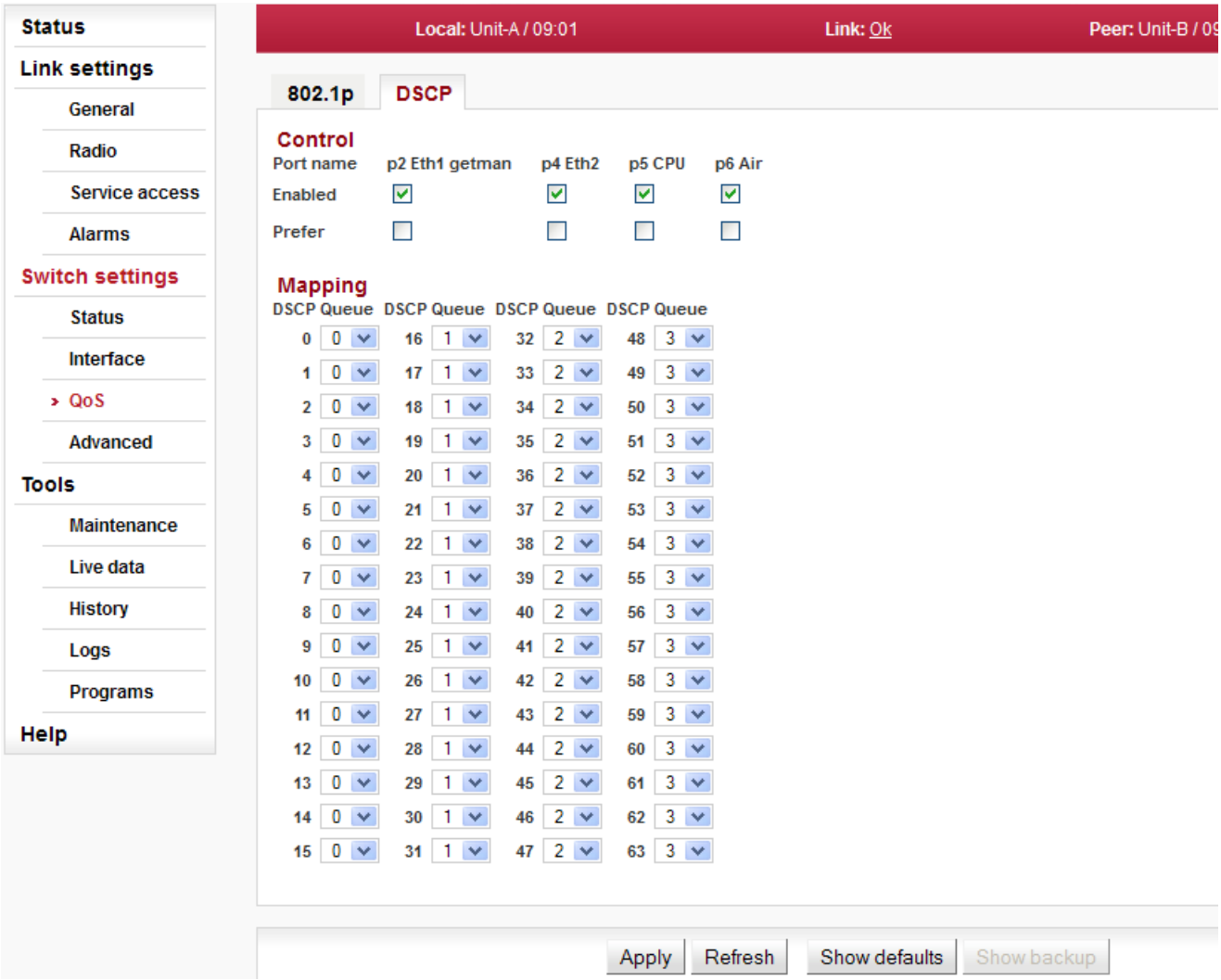


Fig. 7.30: Menu Switch settings - DSCP

The DSCP stands for Differentiated services Code Point which is a 6-bit value stored within the IP header. The QoS techniques using those bits are called DiffServ or Differentiated services.

Port name — Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Enabled — The QoS classification according to DSCP priority bits is enabled/disabled.

Prefer — Enable this parameter to force DSCP priority over 802.p.

When enabled, the IEEE 802.1p Prefer parameter is automatically disabled.

DSCP 0..63 — Arranging individual priorities (coded in DS field of IP header) into selected output queue (0..3).

7.5.4. Advanced

According to the Advanced menu proceeds the deciding, through which port the framework should be transmitted from RAy unit.

The processing of framework can be observed on the diagram and in the table. Table columns indicate successive steps and in the rows there is hinted the development of framework parameters.

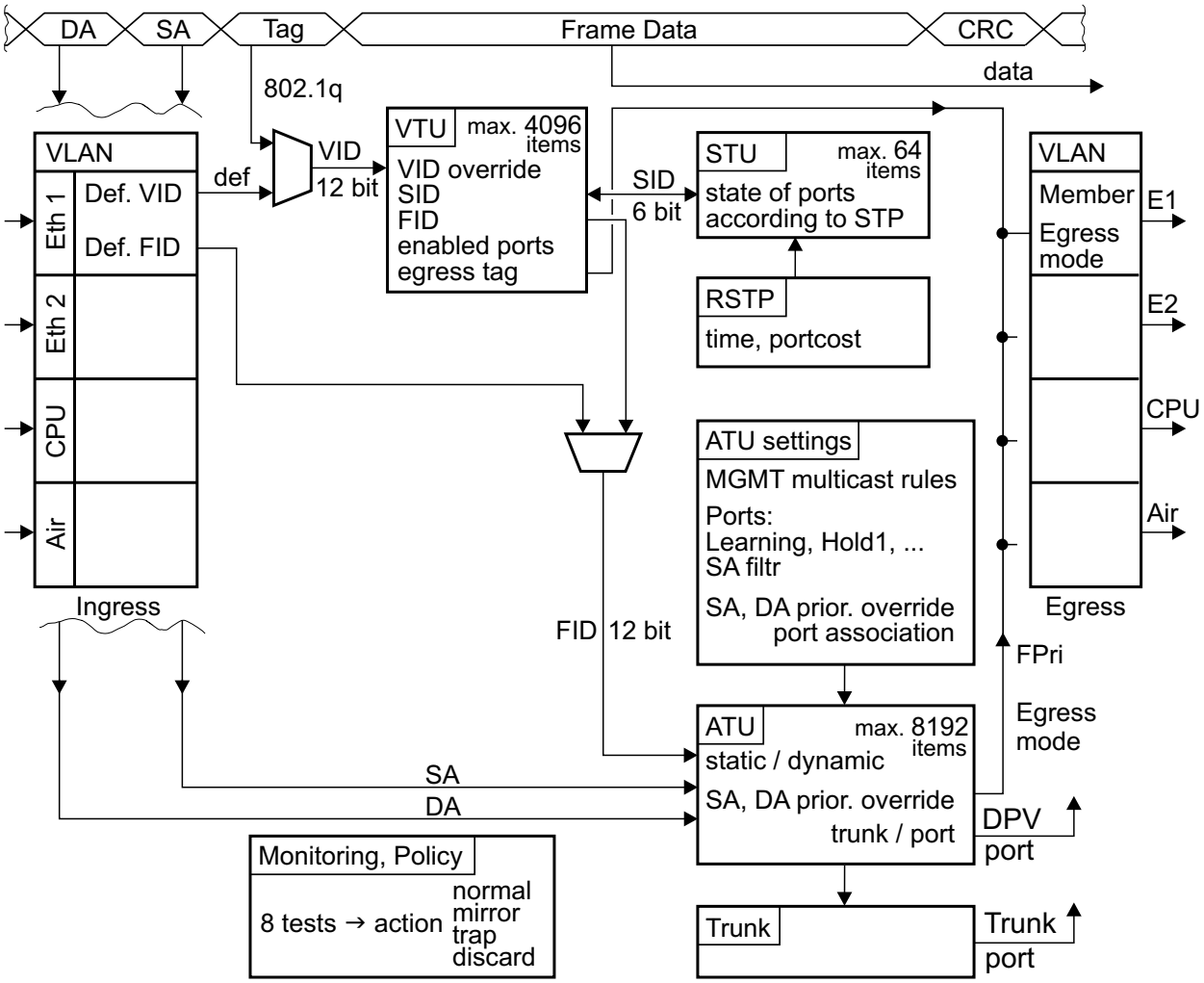


Fig. 7.31: Advanced menu diagram

	Frame	VLAN	VTU	STU	ATU	Trunk
DA, SA	DA, SA				id	
QPri	QoS, DSCP	by port	by VLAN		DA, SA	
VID	VID	def. VID	id			
SID			SID	id		
FID		by port	by VLAN		id	
Trunk					ATU-Trunk	id
port egress		by port		RSTP	ATU-Port	Trunk
tag egress		Egress mode	Member tag			

An indicative description of the function of each block:

Frame

An incoming frame contains the destination MAC address DA and the source address SA. The VLAN 802.1p priority can be contained in the Ethernet header and the DSCP priority in the IP header. If the frame is a member of a VLAN, it carries it's VID number and 802.1q priority in the tag.

VLAN

A frame is received through ports Eth1, Eth2, Air or from microwave CPU. The head of the frame may change at this time based on parameters set in the VLAN menu.

All untagged frames are assigned a VID. A tagged (VLAN) framework can have its own VID overwritten by a default VID.

The packet priority can be ovewritten according to parameter menus QoS, VLAN and ATU.

The FID for searching in the ATU table is allocated to the frame within the VLAN menu (by the input port) or from the corresponding VID in the VTU table.

Member parameter can limit the allowed output direction of ports.

Frames sent from a unit transfers through an output port. The Egress mode parameter bound to the port either adds or removes the VLAN tag.

VTU

Values in the VID determine search results from the VTU table. These are created manually. The SID index (enabled ports in terms of STP) FID index (for searching in the address table ATU) taken from this search result are assigned to the frame. This FID will overwrite the FID from menu VLAN.

Based on this, the VTU can also overwrite the priority of this frame.

The permitted output ports and method of working with VLAN tag on the output are also defined here.

STU

The Spanning tree protocol in this table maintains the status of ports from the viewpoint of the authorized network throughput and the learning of routing. Protocol MSTP is used.

Each VTU entry uses some of the entries in the STU. Entries in the ATU are created in accordance with these assigned states.

The port state behaviour is determined by the STP.

ATU settings

Any assigned parameters dictate how the ATU table should be used.

The Global section of this menu provides for passage of MGMT frames (e.g. BPDU).

In the Port settings section, the behaviour of individual port is defined:

- Behaviour of the ATU table in terms of automatically creating records (Learning, Hold at 1, ATU refresh, Learn limit).

- Discarding frames according to the source addresses.

- Handling frames with unfamiliar destination addresses.

- The frames' priority can be overridden by the SA or the DA.

ATU

The ATU table determines the output port on the RAy according to the DA in the frame.

Records are arranged according to the FID and the MAC addresses.

The table is created and maintained based on informations contained in incoming frames (learning). Manual recording is also possible.

The record can be dynamic or static.

Priority frames with a static record can be overridden by the SA or DA.

The results of searching the ATU provide the set of output ports or trunk number.

RSTP

The RSTP demon turns off redundant paths through the network (switch ports), or re-activates them in the case of failure in other branch.

The Global section of this menu contains switch priority for the RSTP and necessary time constants.

The Port settings section holds the value of each port as seen by the RSTP. This information indicates if the RSTP shuts down or restarts a redundant port if a route is interrupted.

Trunk

The Trunk enables the distribution of data load on multiple ports. The ratio of distribution is determined by parameter Balancing mode.

Abbreviations used in the Advanced menu.

DA, SA	Destination and Source frame address (MAC)
LAN	Local Area Network
VLAN	Virtual LAN, menu of parameters related to the VLAN
VID	VLAN network ID
VTU	VLAN Table Unit - according to VID assignes SID and FID to the frame
SID	Spanning tree ID - record number for STP
STP	Spanning Tree Protocol - prevents a loop in the network
STU	Spanning Tree Unit - parameters associated with STP
FID	Forwarding Information Database number - according to this runs searching in the table
ATU	Address Translation Unit - conversion FID and DA to number of output port
MGMT	Management frames - service frames of the microwave link: frames "ATU - Entry state = static management" and frames "ATU settings - Reserved..."
BPDU	Bridge Protocol Data Unit - frames used by STP protocol
802.1d	Spanning tree protocol by ports
802.1s	Spanning tree protocol by VLAN
802.1q	tagging of frames (VLAN)
802.1p	priority by 2-nd layer (tagged frames Ethernet)
DSCP	Differentiated Services Code Point - priority by 3-rd layer (IP packet)
QoS	Quality of Service
FPri	Frame Priority - priority in the network
QPri	Queue Priority - priority of the frame inside the switch
Trunk	here in the sense of aggregation ethernet links - conjunction multiple ports into a single line another meaning is VLAN aggregation lines - multiple VLANs on a single port

VLAN

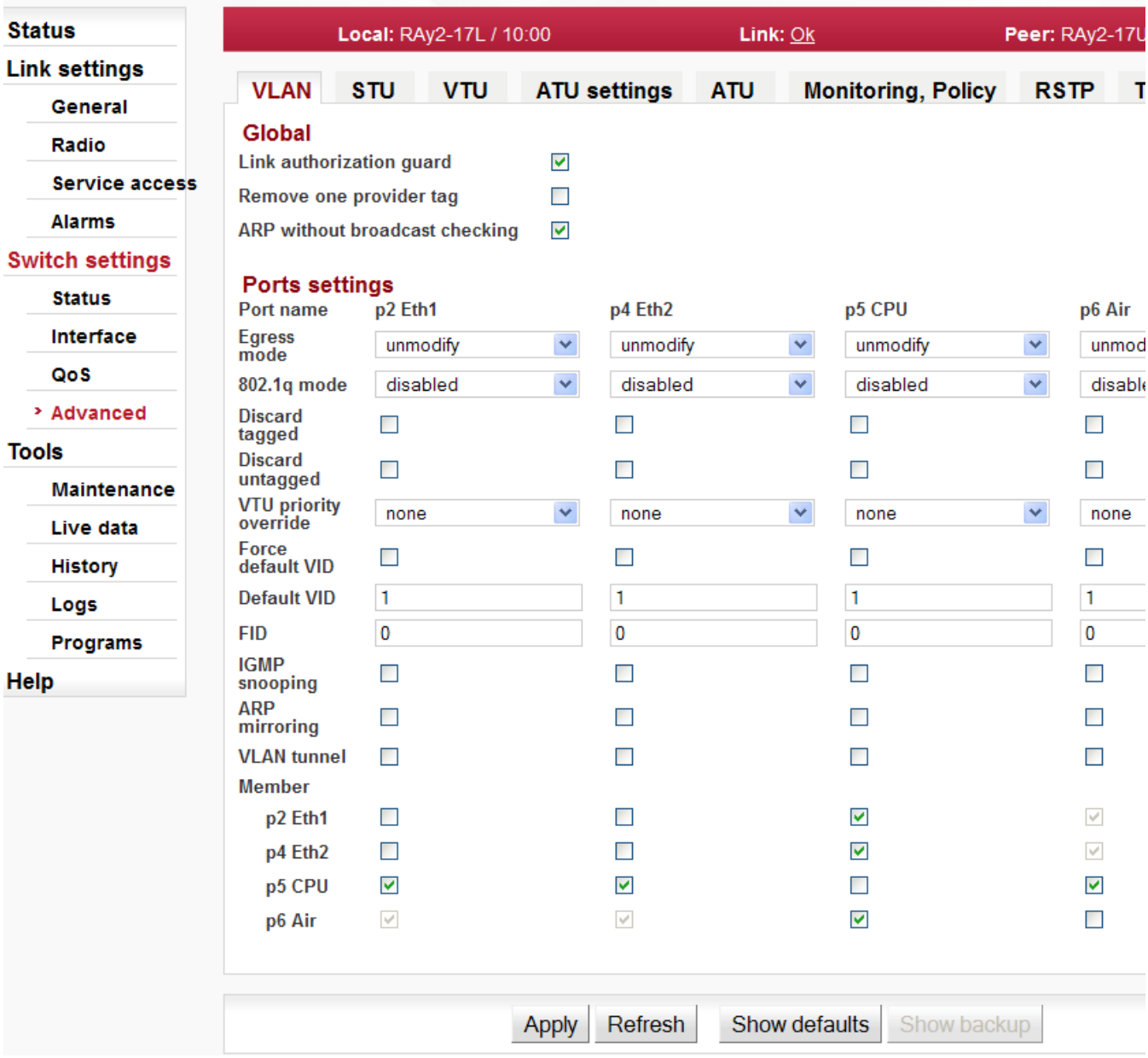


Fig. 7.32: Menu Switch settings - Advanced - VLAN

Setup of VLAN related and global parameters.

Link authorization guard

Remote unit authorization must take place to ensure user data flow between both units. See User manual Section 8.3.3, “Remote unit authorization” for more details.

The Link authorization guard parameter can be used to bypass this authorization requirement.

- Disabled — Remote unit authorization is bypassed. User data flow through the Air channel occurs even if the remote unit is not authorized.
- Enabled — User data flow through the Air channel occurs only if the remote unit is authorized – according to the Remote unit authorization procedure.

Remove one provider tag

When this parameter is enabled and a port is configured as a Provider Port, recursive Provider Tag stripping will NOT be performed. Only the first Provider Tag found on the frame will be extracted and removed. Its extracted data will be used for switching.

When this parameter is disabled and a port is configured as a Provider Port, recursive Provider Tag stripping will be performed. The first Provider Tag's data will be extracted and used for switching, and then all subsequent Provider Tags found in the frame will also be removed. This will only occur if the port's *Ether type* is not 0x8100 (recursive Provider Tag removal cannot be performedSetup of VLAN related when the Provider's Ether Type is equal to 0x8100).

ARP without broadcast checking

Disabled	ARP frames must contain a Broadcast Destination address to be able to access the CPU port.
Enabled	ARP frames only need an Ether type equal to 0x0806 and the frames Destination Address can be any value to be able to access the CPU port. This supports Mirroring ARP replies that are destined to a unicast address.

Port name

Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Egress mode

This parameter determines the make up of frames when they egress this port. The Egress mode behaviour is affected by the Frame mode (menu *Interface – Port advanced – Frame mode*) parameter.

Frame mode ... normal:

unmodify	Frames are transmitted unmodified
untag	Remove the tag from any tagged frame
tag	Add a tag (e.g. according to *Default VID*) to any untagged frame. Ethernet frame type is set to 0x8100.
ether type tag	not used

Frame mode ... provider:

unmodify	Use this mode when *Frame mode* is set to *provider*.
untag	not used
tag	not used
ether type tag	not used

Frame mode ... ether type DSA:

unmodify	not used
untag	not used
tag	not used
ether type tag	Add a tag (e.g. according to "Default VID") to any untagged frame. Ethernet frame type is set according to "Ether type" parameter (menu Switch settings - Interface - Port advanced).

802.1q mode This parameter determines if 802.1q base VLANs are used along with port based VLANs for this Ingress port. It also determines the action to be taken if an 802.1q VLAN Violation is detected. VLAN barriers (both port based and 802.1q based) can be bypassed by VLAN Tunnel.

- disabled — Use Port Based VLANs only. The VID assigned to the frame is the port's Default VID which is used as the VID in the Provider Tag if the frame egresses a Provider port.
- fallback — Enable 802.1q for this Ingress port. Do not discard Ingress Membership violations and use the VLAN Table bits if the frames' VID is not contained in the VTU.
  The ingressing frames are not discarded and it doesn't matter if the frames' VID is a member of the VTU.
- check — Enable 802.1q for this Ingress port. Do not discard Ingress Membership violation but discard the frame if its VID is not contained in the VTU.
  The ingressing frames' VID must be configured in the VTU to enable it to ingress. The VTU *Member tag* parameter doesn't have any effect.
- secure — Enable 802.1q for this Ingress port. Discard Ingress Membership violations and discard frames whose VID is not contained in the VTU.
  The ingressing frame is checked fully against the record in the VTU table. The *VID* and the *Member tag* parameters are validated to allow the frame to ingress.

Discard tagged When this parameter is enabled all non-MGMT frames that are processed as tagged are discarded as they enter this switch port. Priority only tagged frames (with a VID of 0x000) are considered untagged. This feature works whether 802.1q is enabled on the port or not.

If the port is configured in Provide Mode and this parameter is enabled, frames that contain an Ether Type that matches the port's PortEType (*Ether type* parameter) that have a non-zero VID will be discarded.

Discard untagged When this parameter is enabled all non-MGMT frames that are processed as untagged, are discarded as they enter this switch port. Priority only tagged frames (with a VID of 0x000) are considered untagged. This feature works whether 802.1q is enabled on the port or not.

If the port is configured in Provide Mode and this parameter is enabled, frames that don't contain an Ether Type that matches the port's PortEType (*Ether type* parameter) that have a non-zero VID will be discarded.

VTU priority override When this parameter is set to anything other than *none*, VTU priority overrides can occur on this port. A VTU priority override occurs when the determined VID of a frame results in a VID whose *Use VID priority* parameter is enabled. When this occurs three (other than *none*) forms of priority overrides are possible:

- none — Normal frame priority processing occurs.
- frame — The *VID priority* value assigned to the frame's VID (in the VLAN database) is used to overwrite the frame's previously determined FPri (frame priority). If the frame egresses tagged the priority in the frame will be this new *VID priority* value - the frame is permanently modified.

queue — The *VID priority* value assigned to the frame's VID (in the VLAN database) is used to overwrite the frame's previously determined QPri (queue priority). The QPri is used internally to map the frame to one of the egress queues inside the switch. QPri override will not affect the contents of the frame in any way.

frame+queue — Both the above overrides take place on the frame.

The VTU Priority override has higher priority than the port's Default Priority and the frame's IEEE and/or IP priorities. The priority determined by the frames' VID can however be overridden by the frames' SA and/or DA Priority Overrides.

Force default VID — Force to use Default VID. When 802.1q is enabled on this port and this parameter is enabled, all Ingress frames' VID are ignored and the *Default VID* is assigned and replaced into the frame (if the frame egresses tagged). When this parameter is disabled all IEEE802.3ac Tagged frames with a non-zero VID use the frames' VID unmodified.

When 802.1q is disabled on this port, this bit has no effect.

Default VID — Default VLAN Identifier. When 802.1q is enabled on this port the Default VID parameter is used as the IEEE Tagged VID added to untagged or priority tagged frames during egress that ingressed from this port. It is also used as a tagged frame's VID if the frame's VID was 0x000 (i.e., it is a priority tagged frame) or if the port's *Force Devault VID* is enabled.

When 802.1q is disabled on this port, the Default VID field is assigned to all frames entering the port (whether tagged or untagged). This assignment is used internal to the switch.

FID — Port's Default Filtering Information Database (FID). This parameter can be used with non-overlapping VLANs to keep each VLAN's MAC address mapping database separate from the other VLANs. This allows the same MAC address to appear multiple times in the address database (at most one time per VLAN) with a different port mapping per entry. This field is overriden by the FID returned from a VTU hit and it should be zero if not used. It must be a unique number for each independent, non-overlapping, address database if used.

IGMP snooping — IGMP and MLD Snooping. When this parameter is enabled and this port receives an IPv4 IGMP frame or an IPv6 MLD frame, the frame is switched to the CPU port overriding the destination ports determined by the DA mapping. When this parameter is disabled IGMP/MLD frames are not treated specially.

IGMP/MLD Snooping is intended to be used on Normal Network or Provider ports only.

ARP mirroring — When this parameter is enabled non-filtered Tagged or Untagged Frames that ingress this port that have the Broadcast Destination Address with an Ethertype of 0x0806 are mirrored to the CPUDest port. This mirroring takes place after the ingress mapping decisions to allow ARPs to get to a CPU that is otherwise isolated. When this bit is cleared to a zero no special ARP handling will occur.

VLAN tunnel — When this parameter is disabled, the port based VLANs defined in the VLAN Table, 802.1q VLANs defined in the VTU and Trunk Masking are enforced fo ALL frames.

When this parameter is enabled, the port based VLAN Table masking, 802.1q VLAN membership masking and the Trunk Masking are bypassed for any frame entering this port with a DA that is currently 'static' in the ATU. This applies to unicast as well as multicast frames.

While enabled, the Unicast frames with the management CPU DA can go from the Eth1 and Eth2 ports in to the CPU port. The static record with the CPU DA in the ATU table has to be configured (it is pre-configured by default).

Member (VLAN Table)

The In Chip Port based VLAN Table contains parameters used to restrict the output ports to which an input port can send frames. These parameters (VLANTable bits) are used for all frames, except for MGMT frames, even if 802.1q is enabled on this port. These parameters restrict where a port can send frames to (unless a VLANTunnel frame is being received). If ForceMap (Learning) is enabled, these parameters indicate which port or ports all frames that ingress this port are sent to overriding the mapping from the address database.

The default setting prevents sending frames from Eth1 to Eth2 and vice versa. This is very important for separating different networks (e.g. different customers) connected to separate user ports.

The Link authorization guard affects the user data flow through the Air channel. When the Link authorization guard is enabled, the user Ethernet ports to Air port connection control is disabled. Parameter status of user Ethernet to Air port connection changes dynamically according to Link authorization status.

STU

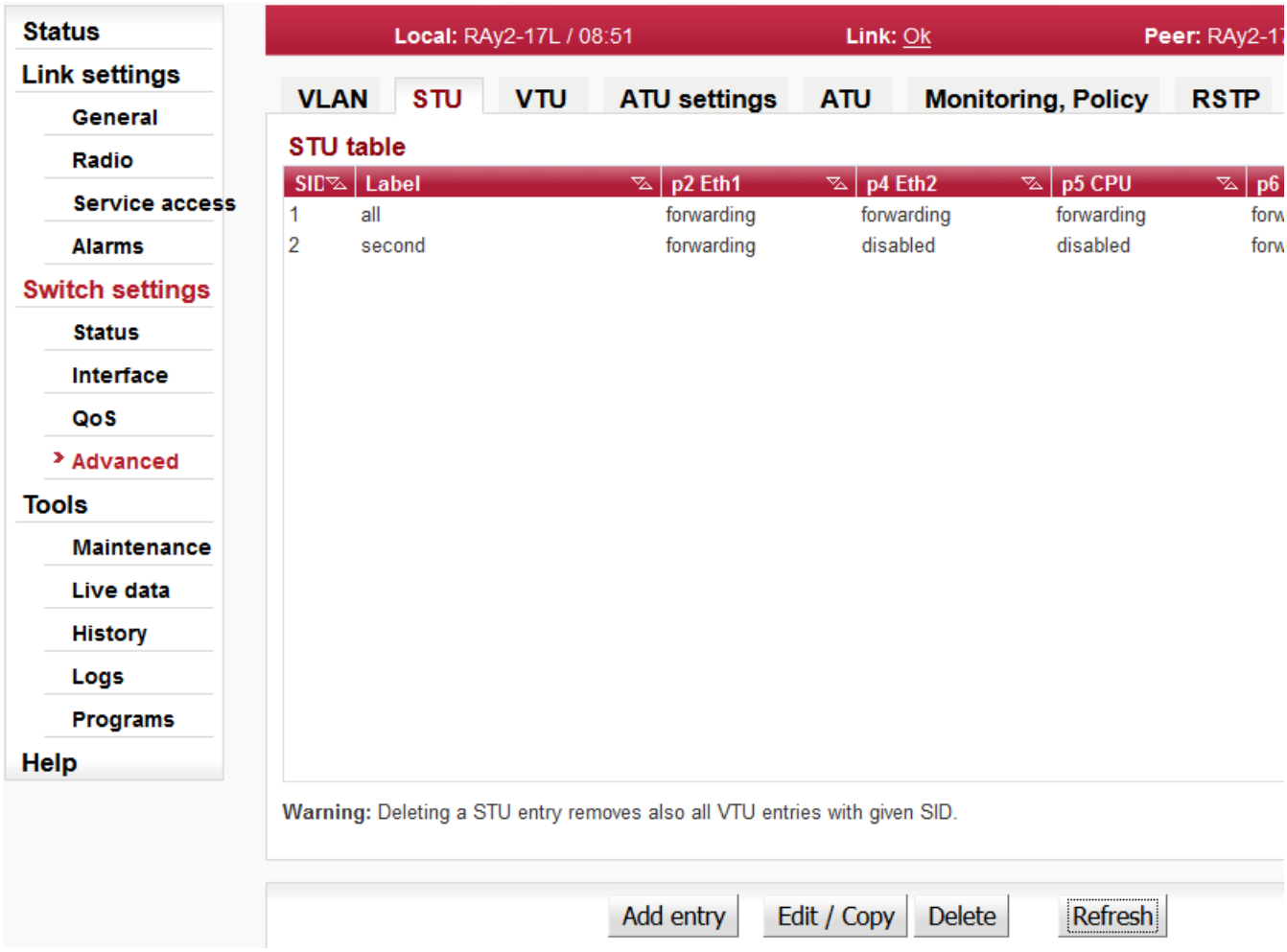


Fig. 7.33: Menu Switch settings - Advanced - STU

The per VLAN Spanning Tree Unit (STU) in the device supports user commands to access and modify the contents of the Port State database.

Primary key The icon indicates which parameter field is taken as the unique identifier in the database. This field entry ensures each record is unique and must not be duplicated.

SID VTU 802.1s (MSTP) Port State Information Database number. This parameter indicates the SID number that is associated with the 802.1s *Port state* parameter.

It is essential to define the SID to be able to create records in the VTU (VLAN Table).

Label A custom string label for a STU entry.

Port state This parameter is used to support 802.1s per VLAN spanning tree. Port states (bellow) are valid for frames with a VID that is associated to this SID:

- disabled — Use non-VLAN Port States (i.e., the port's default Port State) for this port.
- blocking /listening
- learning

forwarding

This *Port state* takes precedence over the port's Port State bits unless the port's Port State (menu *Interface – Port advanced – State*) is Disabled (which prevents all frames from flowing).

Add entry Add a new STU database entry.

Edit Press the Edit button to open the configuration dialog of the selected STU database record.

NOTE: Should the Primary key value be modified, the "other" record - identified by the entered Primary key - is added (if it doesn't exist yet) or modified (if it exists already).

Delete Delete the selected STU database record.

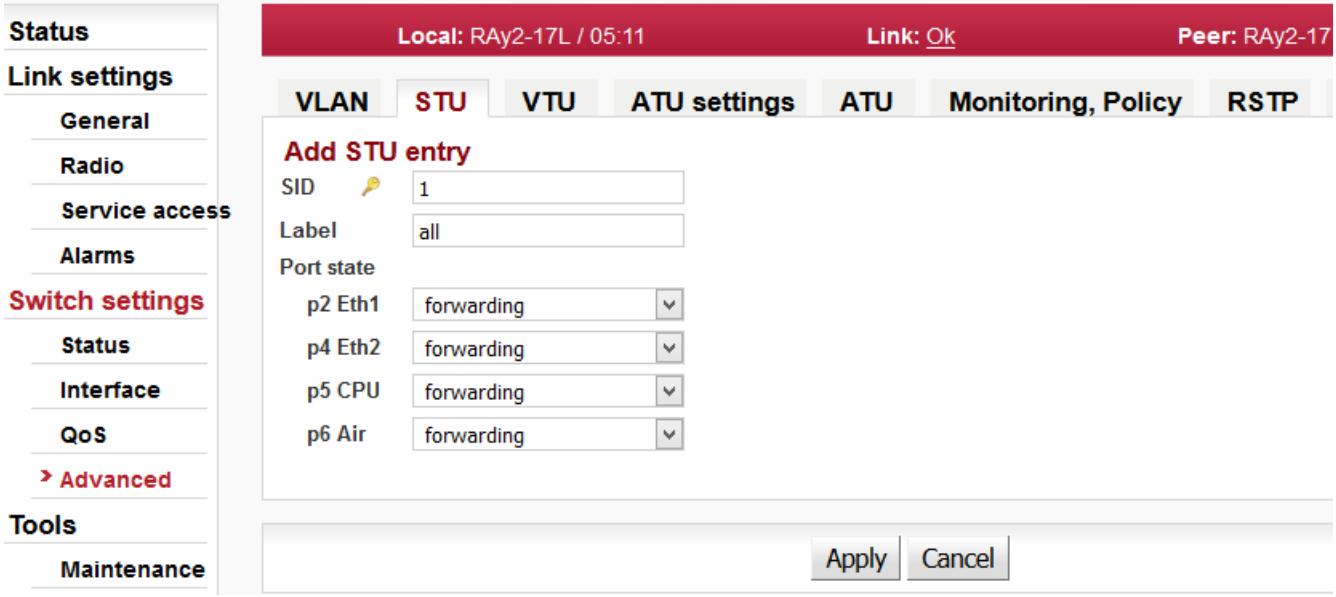


Fig. 7.34: Menu Switch settings - Advanced - STU - edit

VTU

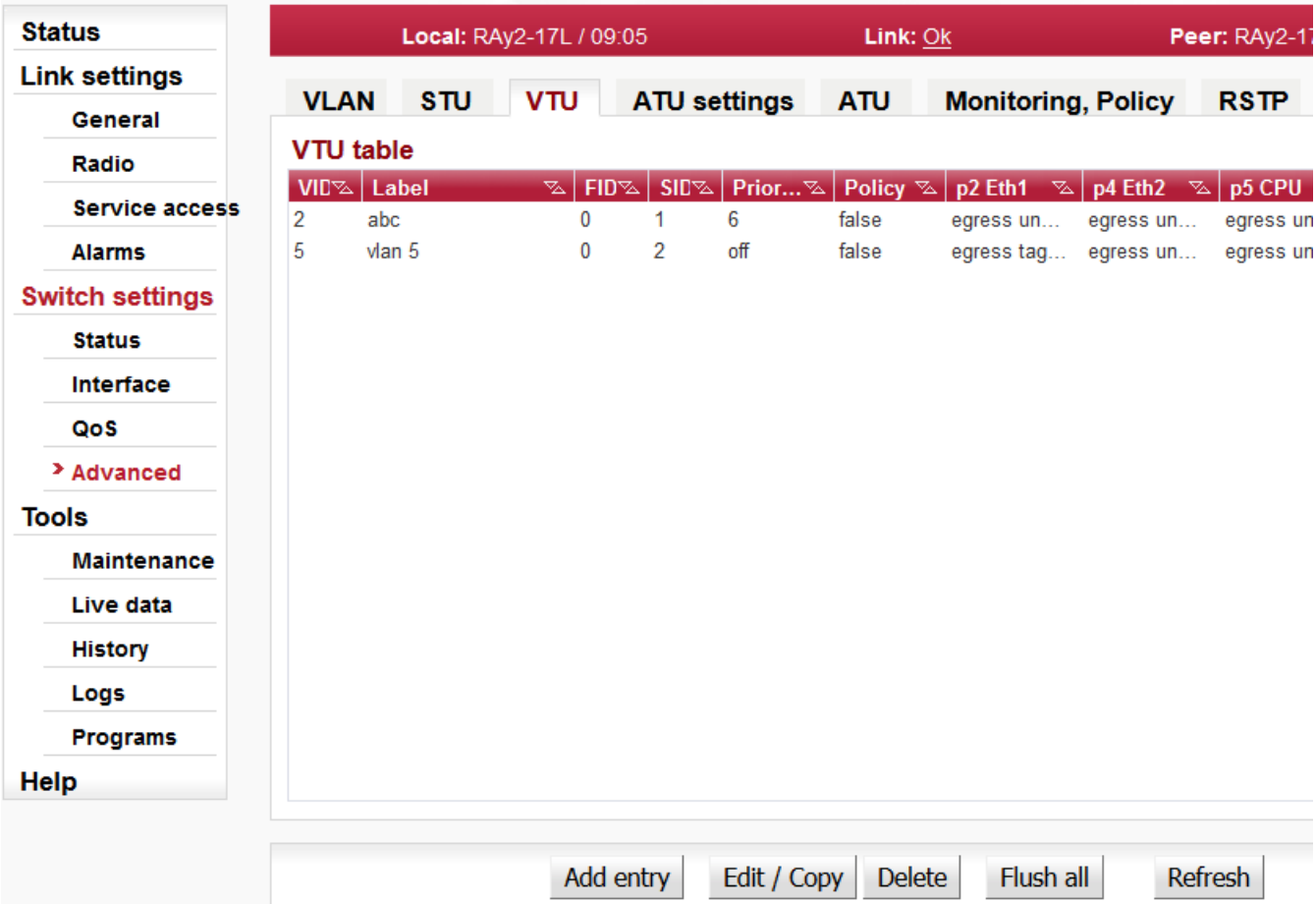


Fig. 7.35: Menu Switch settings - Advanced - VTU

The VTU (VLAN Table Unit) records form the VLAN Table.

Primary key The icon indicates which parameter field is taken as the unique identifier in the database. This field entry ensures each record is unique and must not be duplicated.

VID VLAN ID. This parameter indicates the VID number that is associated with the Member tag, VTU Priority, VTU policy and the FID (Forwarding Information Database number).

Label A custom string label for a VTU entry.

FID Forwarding Information Database number. If separate address databases are used, this parameter indicates the address database number to use for all frames assigned with this VID. All MAC DA look-ups and SA learning will refer to the address database number defined by the FID associated with the frame's VID. Multiple VID's can use the same FID. If separate address databases are not used, the FID must be zero. The ATU database records are joined with the VTU database records via this number.

SID 802.1s Information Database Number. If 802.1s per VLAN spanning tree is being used, this parameter indicate the spanning tree instance number to use for all frames assigned with this VID. Multiple VID's can use the same SID. The STU database records are joined with the VTU database records via this number.

Use VID priority VID Priority Override. This parameter is used to indicate that frames assigned with this VID can have their priority overridden with the *VID priority* value (see below) if the port's *VTU priority override* parameters is enabled to do so. See *VTU priority override* for more details.

VID priority VID Priority override value when enabled by the *Use VID priority* parameter (see above). Used for priority override on ingressing frames. Enabling a priority on a VID will override the frame's priority only if the port's *VTU priority override* parameter is enabled to do so.

VID policy This parameter is used to indicate that frames assigned with this VID can have Layer 2 Policy actions applied to it if the port's *Policy VTU* (menu Advanced/Monitoring, Policy/Policy) is enabled to do so.

Member tag This parameters is used to indicate which ports are members of the VLAN (i.e, with the given VID) and if these VLANs frames should be tagged or untagged, or unmodified when exiting the port as follows:

egress unmodified	Port is a member of this VLAN and frames are to egress unmodified.
egress untagged	Port is a member of this VLAN and frames are to egress Untagged.
egress tagged	Port is a member of this VLAN and frames are to egress Tagged.
not member	Port is not a member of this VLAN. The result is that frames assigned with this VID can not egress this port.

This parameter takes effect only if the *802.1q mode* parameter (see menu Advanced/VLAN) is set to *secure* mode.

Add entry Add a new VTU database entry.

Edit Press the Edit button to open the configuration dialog of selected VTU database record.

NOTE: Should the Primary key value be modified, the "other" record - identified by the entered Primary key - is added (if it doesn't exist yet) or modified (if it exists already).

Delete Delete the selected VTU database record.

Flush all Delete the whole VTU database.

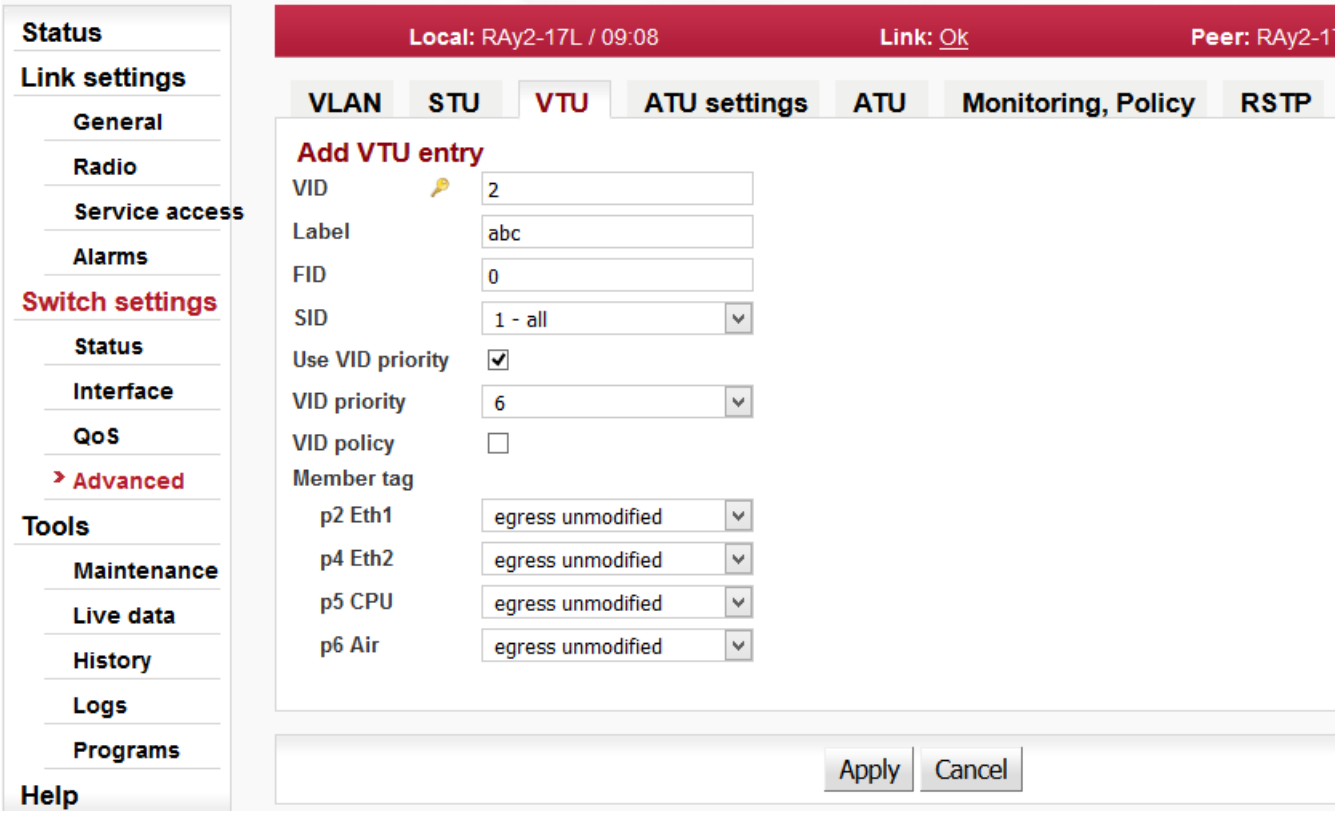


Fig. 7.36: Menu Switch settings - Advanced - VTU - edit

ATU settings

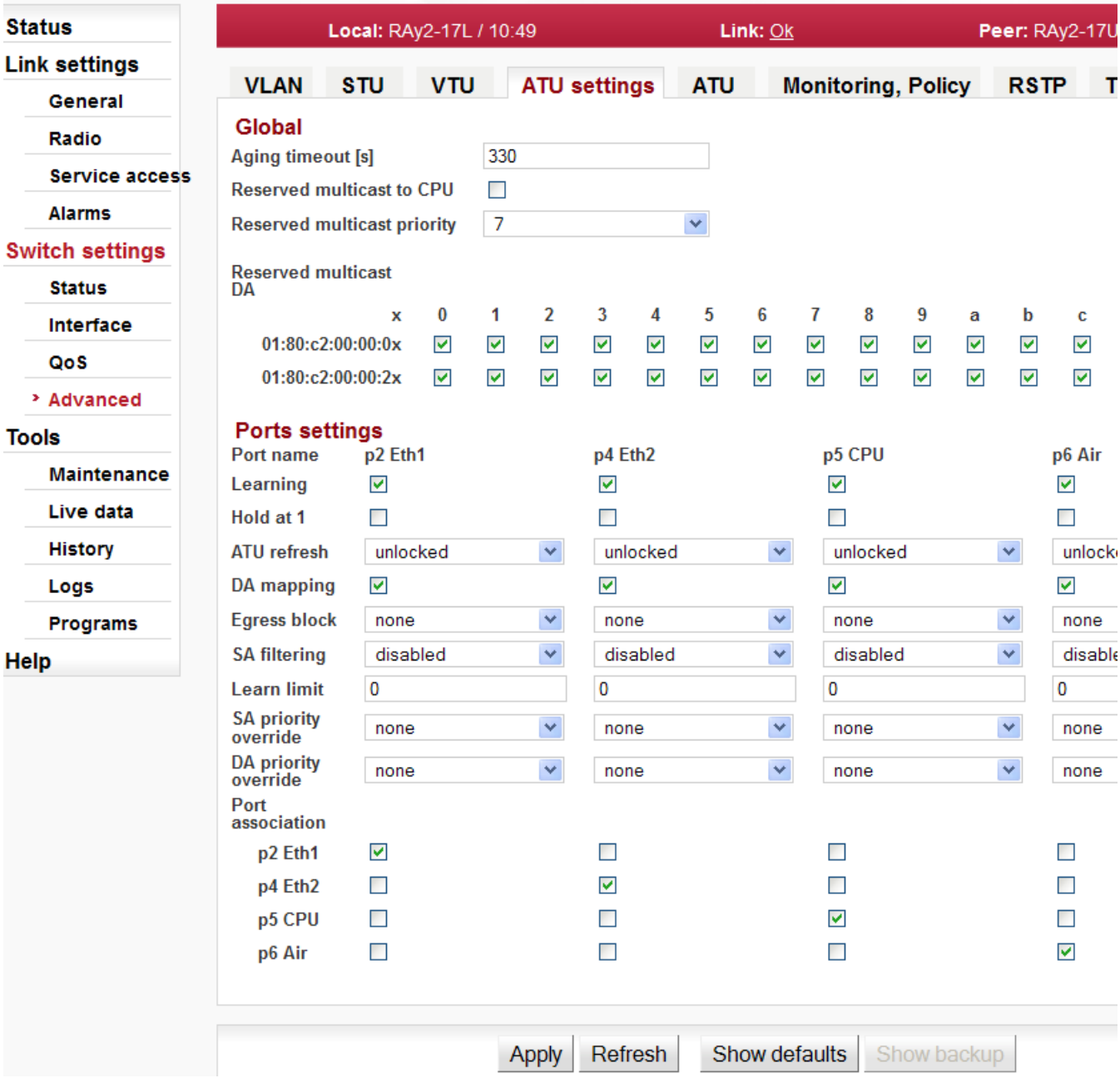


Fig. 7.37: Menu Switch settings - Advanced - ATU settings

Setup of ATU (Address Translation Unit) table related parameters.

Aging timeout [s] ATU age time. This value determines the time that each ATU Entry remains valid in the database, since its last access as a source address, before being purged.

The default value is 330 seconds.

The minimum age time is 15 seconds.

The maximum age time is 3825 seconds (almost 64 minutes).

If the Age Time is set to 0 the Aging function is disabled and all learned addresses will remain in the database forever.

Reserved multicast to CPU When this parameter is enabled, frames with a Destination Address in the range 01:80:C2:00:00:0x or 01:80:C2:00:00:2x, regardless of their VLAN membership, will be considered MGMT frames and sent to the CPU port. See the "RSTP, RSTP enable" parameter.

Reserved multicast priority This parameter sets the priority of the frames affected by *Reserved multicast to CPU* parameter.

Reserved multicast DA This parameter enables individual multicast DA addresses to be affected by *Reserved multicast to CPU* parameter.

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Learning (ForceMap) When this parameter is disabled, normal frame processing occurs.

When this parameter is enabled, all received frames will be considered MGMT (MGMT=Management frames, frames that can tunnel through Blocked ports) and are mapped to the port or ports defined in the VLANTable bits overriding the mapping from the address database. The forcing function is needed to get BPDU frames to egress specific ports by the CPU for the Spanning Tree Protocol. ForceMapped frames will egress ports that are not in the Disabled port state (i.e., they are MGMT frames and will egress via Blocked ports). This parameter is accessible by the CPU's Ingress Header so the CPU can enable and disable MGMT and forcing on a frame by frame bases.

NOTE: Learning is disabled on MGMT frames, so enabling this parameter also disables learning on frames entering this port.

Hold at 1 Hold Aging ATU Entries at an Entry State value of 1. When this parameter is disabled, a zero normal Aging occurs for ATU entries associated with this port. When this parameter is enabled ATU entries associated with this port will age down to an Entry state of 1 but will not go to 0. This feature can be used (for example) to keep dynamic records in the ATU table.

ATU refresh

unlocked	Normal address learning is enabled
known	Auto refreshing of known addresses will occur even if this port is Locked. Already known addresses will be auto refreshed (i.e., their Entry State will be updated to 0x7 whenever this address is used as a source address in a frame on this port) even when this port is Locked.
locked	CPU directed learning (needed for 802.1X MAC authentication) is enabled. Automatic SA learning and refreshing is disabled in this mode.

DA mapping When this parameter is enabled, normal switch operation occurs where a frame's DA is used to direct the frame out of the correct port. When this parameter is disabled the frame will be sent out of the port defined by EgressFloods even if the DA is found in the address database. The static ATU table records are used, even in *DA mapping* disabled status.

Egress block Egress Flooding mode. The DA of every unicast and multicast frame is searched in the ATU. If the DA is found in the address database it is considered known. If it is not found it is considered unknown. Frames with known DA's are not affected by this register.

Frames with unknown DA's generally flood out all the ports (except the port they originally came in on). This register can be used to prevent frames with unknown DA's from egressing this port as follows:

unknown	Do not egress any frame with an unknown DA (unicast or multicast)
unknown multicast	Do not egress any frame with an unknown multicast DA
unknown unicast	Do not egress any frame with an unknown unicast DA
none	Egress all frames with an unknown DA (unicast and multicast)

SA filtering Source Address Filtering method:

disabled	No frame will be filtered (i.e. discarded) as a result of the contents of its Source Address field.
drop on lock	Ingressing frames will be discarded if their SA field is not in the ATU's address database (i.e. it's a new or unknown Source Address) or if this port's bit is not set in the PortVec bits for the frames' SA (i.e. this port is not the source port for that MAC address). Used for MAC based 802.1X.
drop on unlock	Ingressing frames will be discarded if their SA field is in the ATU's address database as a Static entry with a PortVec of all zeros. Used to discard frames from known untrusted sources.
drop to CPU	Ingressing frames will be mapped to the CPUDest if their SA field is in the ATU's address database as a Static entry with a PortVec of all zeros and the frame is not otherwise filtered. Otherwise, the frames will be discarded if their SA field is not in the ATU's address database (i.e. it's a new or unknown Source Address) or if this port's bit is not set in the PortVec bits for the frames' SA (i.e. this port is not the source port for that MAC address). This mode is a form of MAC based 802.1X where some frames can be forced to the CPU for further authentication prior to full authorization.

Learn limit (LearnLimit) When this parameter is set to zero, normal address learning and frame policy occurs.

When this parameter is non-zero the number of MAC addresses that can be learned on this port are limited to the value of this parameter. Automatic learning and frame policy will occur normally until the number of unicast MAC addresses auto-learned from this port reaches the port's LearnLimit (addresses that were learned from this port but were aged out are not counted - i.e., this register limits the number of 'active' unicast MAC addresses associated to this port). When the LearnLimit has been reached any frame that ingresses this port with a source MAC address not already in the address database that is associated with this port will be discarded (the port will act as if the port is Locked and the port's DropOnLock SAFiltering mode is set). Normal auto-learning will resume on the port as soon as the number of 'active' unicast MAC addresses associated to this port is less than the LearnLimit (due to address aging).

Care is needed when enabling this feature:

Enable "Learn to all" (GL1-0x0A:11:3 Learn2All=1)

Set *SA filtering* to *disabled* or *drop on unlock* (PORT-0x04:14 SAFiltering[0]=0)

Safe procedure:

Disable or block the ports (PORT-04.1 PortState[1]=0).

Flush all non-static adresses in the ATU.

Define the desired limit for the ports.

Re-enable the ports.

SA priority override

When any other than "none" mode is selected, SA ATU priority overrides can occur on this port. An SA ATU priority override occurs when the source address of a frame results in an ATU hit where the SA's MAC address returns an EntryState that indicates Priority Override. When this happens three forms of priority overrides are possible (other than *none*):

none	Normal frame priority processing is active.
frame	PRI value assigned to the frame's SA (the *MAC priority* field in the ATU database) is used to overwrite the frame's previously determined frame priority (FPri). If the frame egresses, the tagged priority in the frame will be this new PRI value.
queue	The two upper bits of the PRI value assigned to the frame's SA (the *MAC priority* field in the ATU database) are used to overwrite the frame's previously determined queue priority (QPri). The QPri is used internally to map the frame to one of the egress queues inside the switch. QPri override will not affect the contents of the frame in any way.
frame+queue	Both above overrides take effect on the frame

The SA ATU Priority Override has a higher priority than the port's Default Priority, the frame's IEEE and/or IP priorities and the VTU Priority Override. The priority determined by the frame's SA can however be overridden, by the frame's DA Priority Override.

DA priority override

When any other than *none* mode is selected, the DA ATU priority overrides can occur on this port. A DA ATU priority override occurs when the source address of a frame results in an ATU hit where the DA's MAC address returns an EntryState that indicates Priority Override. When this occurs three forms of priority overrides are possible (other than *none*):

none	Normal frame priority processing is active.
frame	PRI value assigned to the frame's DA (the *MAC priority* field in the ATU database) is used to overwrite the frame's previously determined frame priority (FPri). If the frame egresses the tagged priority in the frame will be the new PRI value.
queue	The two upper bits of the PRI value assigned to the frame's DA (the *MAC priority* field in the ATU database) are used to overwrite the frame's previously determined queue priority (QPri). The QPri is used internally to map the frame to one of the egress queues inside the switch. QPri override will not affect the contents of the frame in any way.
frame+queue	Both of the above overrides take place on the frame

The DA ATU Priority Override has the highest priority over the port's Default Priority, the frame's IEEE and/or IP priorities, the VTU Priority Override and the SA Priority Override.

Port association (PAV)

Port Association Vector for ATU learning. The value in these bits (one bit per port) is used as the port's DPV on automatic ATU Learning or Entry_State refresh whenever these bits contain a non-zero value. When these bits are all zero, automatic Learning and Entry_State refresh is disabled on this port.

For normal switch operation, this port's bit should be the only bit set in the vector. These bits must only be changed when frames are not entering the port.

The PAV bits can be used to set up port trunking (along with the VLANTable bits). For the two ports that form a trunk, set both of their port's bits in both port's PAV registers (this Port association parameter for both ports of the trunk), then use the VLANTable to isolate the two ports from each other, or to use the Trunk Mask table to steer the traffic from the other ports down the desired trunk line of the pair using DA/SA Load Balancing.

ATU

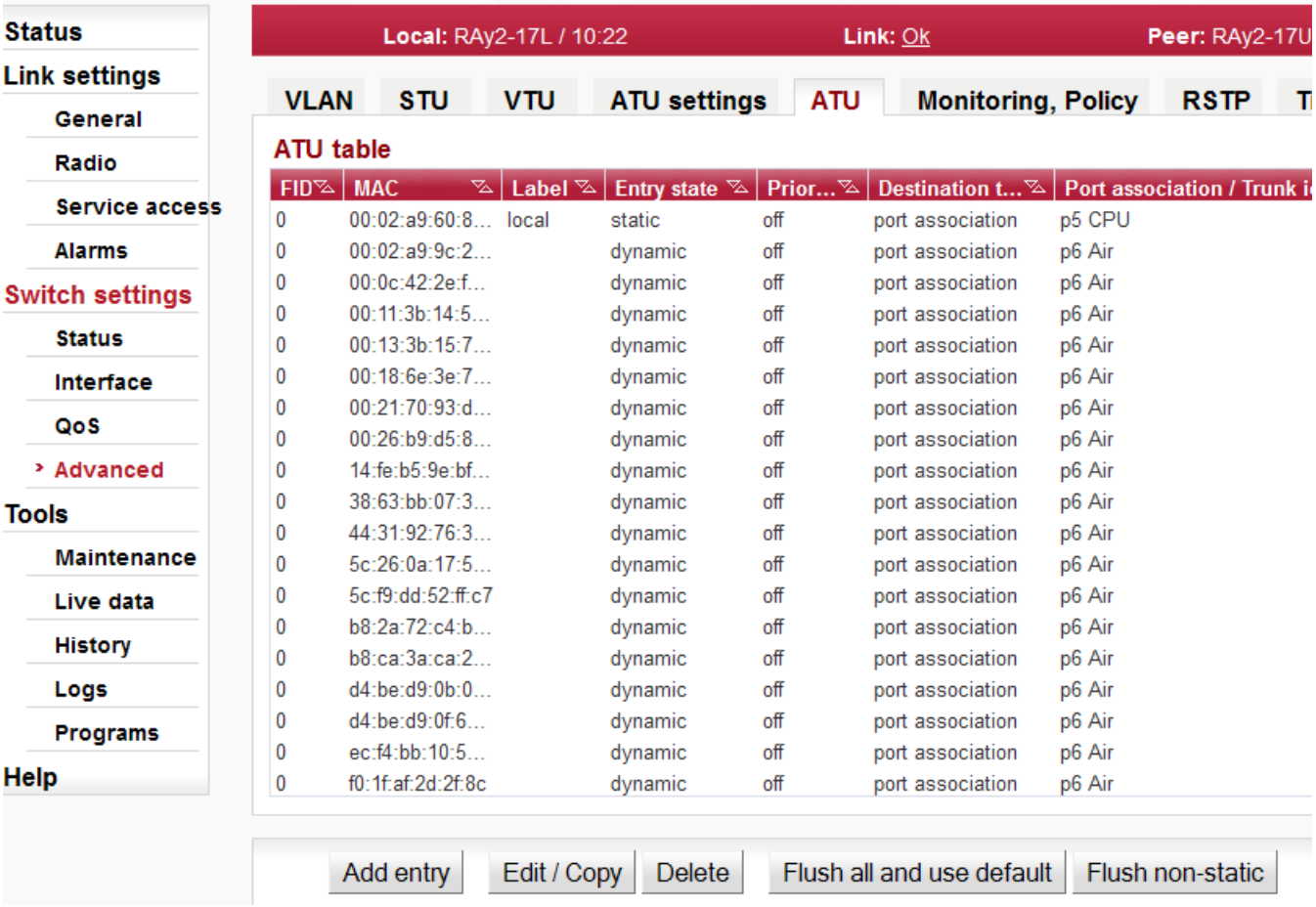


Fig. 7.38: Menu Switch settings - Advanced - ATU

The Address Translation Unit (ATU) in the device supports user commands to access the contents of the MAC address database.

There is one static record which can't be deleted. This is the management CPU record. The unicast frames directed to management are allowed to access the CPU port. The *VLAN tunnel* parameter is also used to enable the AP frames to access the CPU port.

Primary key The icon indicates which parameter field is taken as the unique identifier in the database. This field entry enis taken as the unique identifiersures each record is unique and must not be duplicated.

FID Forwarding Information Database number. If multiple address databases are not being used, this parameter must remain zero. If multiple address databases are being used, this parameter is used to set the desired address database number that is to be associated with this ATU Entry's MAC Address. When frames ingress the switch, the VID assigned to the frame is used to access the VTU. The VTU returns the FID associated with that VID for MAC address lookups in to the ATU.

MAC MAC address associated with this ATU entry in the database number defined by the FID.

Label A custom string label for an ATU entry.

Entry state The Entry state parameter is used to determine the entry's age or its type as follows:

static	Use for ordinary static entry.
static policy	Use for *Policy DA* and/or *Policy SA* (menu *Switch settings – Advanced – Monitoring – Policy*).
static non rate limiting	Use for *SA non rate limit* and/or *DA non rate limit* (menu *Switch settings – Interface – PIRL*).
static management	This value is used for the mapping of the DA even if the *DA mapping* parameter is disabled (menu *Switch settings – Advanced – ATU settings*).
dynamic	Ordinary dynamic entry.

Use MAC priority Use this parameter to enable the *MAC priority* (see *MAC priority* description).

MAC priority The MAC's Priority override value when enabled by the *Use MAC priority* parameter. Used for priority override on ingressing frames. Enabling a priority on a MGMT MAC address will override all priorities for these MGMT frames. Enabling a priority on a static, non-MGMT MAC address, will only override the frame's priority if the port's *DA priority override* or *SA priority override* parameters are enabled.

Trunk member When this parameter is enabled, the MAC address is a member of a trunk - according to the *Trunk Id* parameter. When this parameter is disabled, the MAC address is associated with port(s) - according to the *Port association* parameter.

Trunk Id The Trunk ID associated with this MAC address.

The port or ports that this DA MAC address is associated with is determined by the *Port association* parameter below.

Use this parameter to ensure the proper unit management CPU is accessed when two units are connected in trunk.

Trunk port assotiation vector Mask of ports associated with this MAC address.

Add entry Add a new ATU database entry.

Edit/Copy Press the *Edit/Copy* button to open the configuration dialog of the selected ATU database record.

NOTE: Should the Primary key value be modified, the "other" record - identified by the entered Primary key - is added (if it doesn't exist yet) or modified (if it exists already).

Delete Delete the selected ATU database record.

Flush all and use default Delete the whole ATU database and create default record(s).

Flush non-static Delete all except static ATU database records.

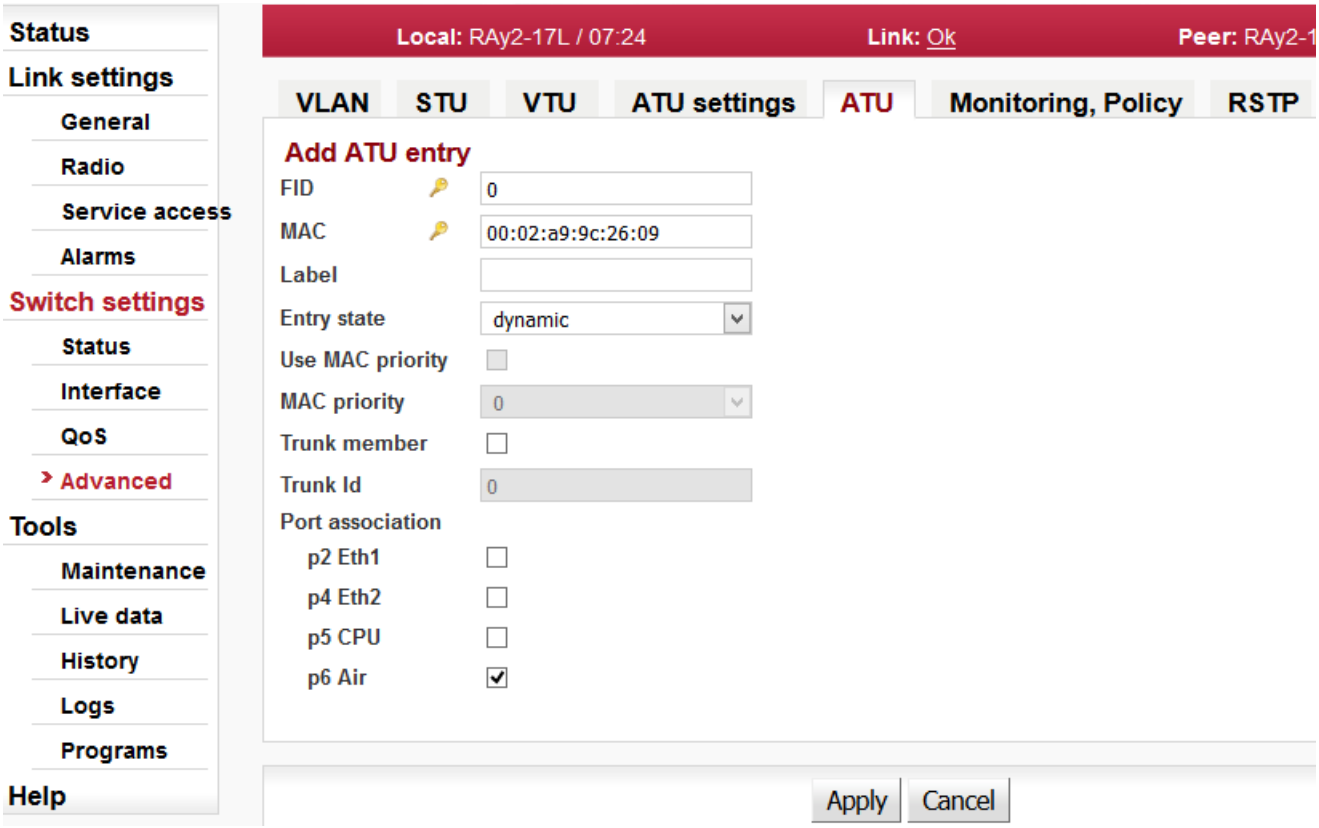


Fig. 7.39: Menu Switch settings - Advanced - ATU - edit

Monitoring, Policy

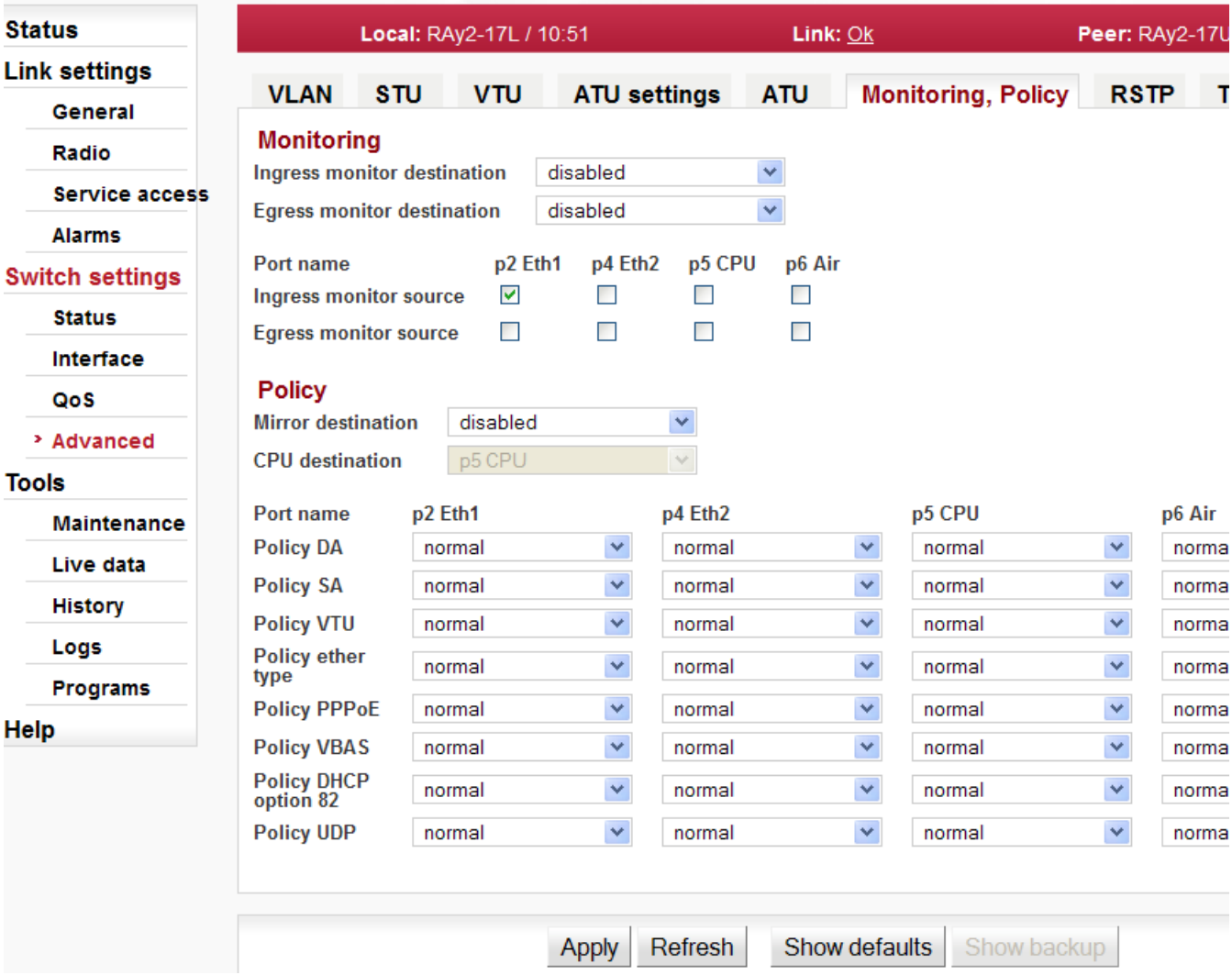


Fig. 7.40: Menu Switch settings - Advanced - Monitoring, Policy

Setup of Monitoring and Policy functions.

The Policy functions allow for special handling of specific types of ingress frames.

Ingress monitor destination Frames that are targeted toward an *Ingress Monitor Destination* leave via the port selected by this parameter. This includes frames received on a port that is enabled to be the *Ingress monitor source*.

Egress monitor destination Frames that are targeted toward an *Egress Monitor Destination* leave via the port selected by this parameter. This includes frames transmitted on a port that is enabled to be the *Egress monitor source*.

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Ingress monitor source

When this parameter is enabled, any frame that ingresses this port is also sent to the *Ingress monitor destination* port. The frame is sent to this port even if it is discarded due to switching policy but the frame will not be forwarded if it contains an error (such as CRC, etc.) or is filtered by ingress rate limiting.

Egress monitor source

When this parameter is enabled any frame that egresses this port will also be sent to the *Egress monitor destination* port. The 802.1q mode and VTU entries on the *Egress monitor destination* port must be set to be the same as they are on the *Egress monitor source* port so the frames egress with the same tagged or untagged information.

Mirror destination

Frames that ingress a port that trigger a policy mirror are mapped (copied) to this port as long as the frame is not filtered or discarded.

CPU destination

CPU destination port can not be changed. It is shown here to better understand the description of some other parameters which interact with the CPU destination port. For example the *trap* value of the *Policy** parameters cause frames to be forwarded to this CPU destination port.

Policy

There are four different operations as a result of a policy:

normal	Normal frame switching.
mirror	Mirror (copy) frame to the *Mirror destination* port.
trap	Trap (re-direct) frame to the *CPU destination* port.
discard	Discard (filter) the frame.

There are eight different policy triggers:

DA	DA Policy Mapping occurs when the DA of a frame is contained in the ATU address database with an Entry State set to *static policy*.
SA	SA Policy Mapping occurs when the SA of a frame is contained in the ATU address database with an Entry State set to *static policy*.
VTU	VTU Policy Mapping occurs when the VID of a frame is contained in the VTU database with the *VID policy* parameter enabled.
ether type	EtherType Policy Mapping occurs when the Ether Type of a frame matches the Ether type parameter of this port.
PPPoE	PPPoE Policy Mapping occurs when the Ether Type of a frame matches 0x8863.
VBAS	VBAS Policy Mapping occurs when the Ether Type of a frame matches 0x8200.
DHCP option 82	DHCP option 82 Policy Mapping occurs when the ingressing frame is an IPv4 UDP with a UDP Destination port=0x0223of 0x0222.
UDP	UDP Policy Mapping occurs when the ingressing frame is a Broadcast IPv4 UDP or a Multicast IPv6 UDP.

RSTP

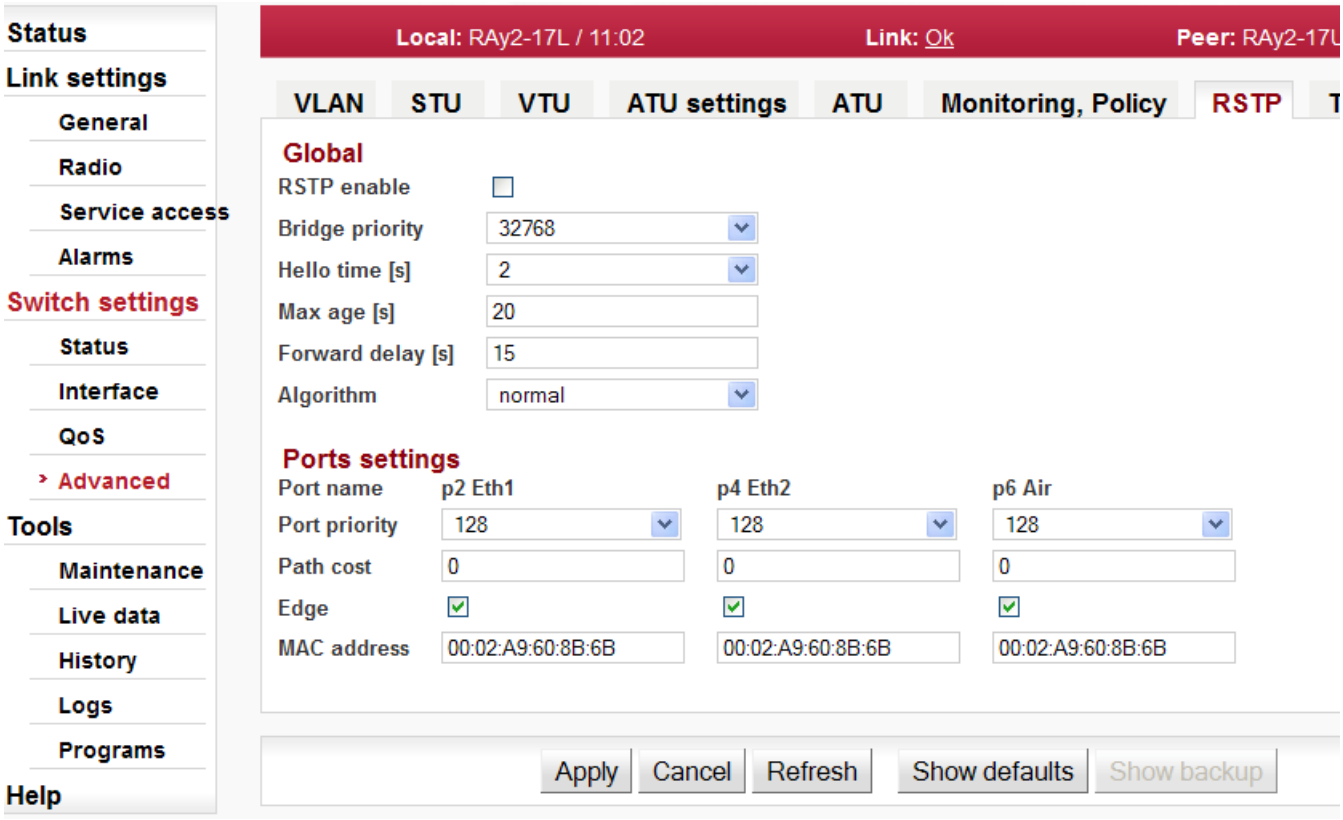


Fig. 7.41: Menu Switch settings - Advanced - RSTP

The Rapid Spanning Tree Protocol (RSTP) is a network protocol that ensures a loop-free topology for any bridged Ethernet local area network. The basic function of RSTP is to prevent bridge loops and the broadcast radiation that results from them. Spanning Tree Protocol also allows network design to include spare (redundant) links to provide automatic backup paths if an active link fails, without the danger of bridge loops, or the need for manual enabling/disabling of these backup links.

RSTP enable When RSTP is enabled, the bridge is created and RSTP service is initiated. Should the RAy2 unit be connected via two Etherent cables (using Eth1 and Eth2 ports), the active participation of the RSTP protocol may be necessary. If the parameter is not enabled, the RAy2 unit transfers the BPDU frames transparently.

NOTE: To enable proper RSTP functionality, these switch parameters has to be set:

Switch settings / Interface / Port advanced / Frame mode / p5 CPU: "ether type DSA"

Switch settings / Interface / Port advanced / Ether type / p5 CPU: "0xDADA"

Switch settings / Advanced / ATU settings / Reserved multicast to CPU: "Enable"

Bridge priority The priority value is a number between 0 and 61440 in incremental steps of 4096, with a default value of 32768. Lower priority values are 'better'. The bridge with the lowest priority value will be elected 'root bridge'.

Hello time [s] The hello time is the time between each Bridge Protocol Data Unit (BPDU) that is sent on a port. Hello time is equal to 2 seconds by default.

Max age [s] The max age timer controls the maximum length of time that passes before a bridge port saves its configuration BPDU information. This time is set to 20 sec by default.

Forward delay [s] The forward delay is the time that is spent in the listening and learning state. This time is equal to 15 sec by default.

Algorithm This parameter sets the bridge's spanning tree algorithm to operate in normal (RSTP) or force it to operate in slow (STP) mode. In normal mode, RSTP reverts back to STP on ports where it sees other hosts operating in STP mode.

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Port priority The ports' priority value is a number between 0 and 240 in increments of 16, with a default value of 128.

Path cost The Path cost can be set automatically or manually. Entering the value of zero sets this parameter automatically. The automatic setup is based on link speed.

Edge Selecting the checkbox sets the port as an "edge" port. If a port is an edge port it is assumed to be a leaf link in the graph, not connected to any other bridges. Receiving any STP BPDU's on a port configured as an edge port temporarily overrides edge port behaviour for the port.

MAC address The ports' default MAC addresses are the same as the MAC address of the RAy2 unit.

Trunk

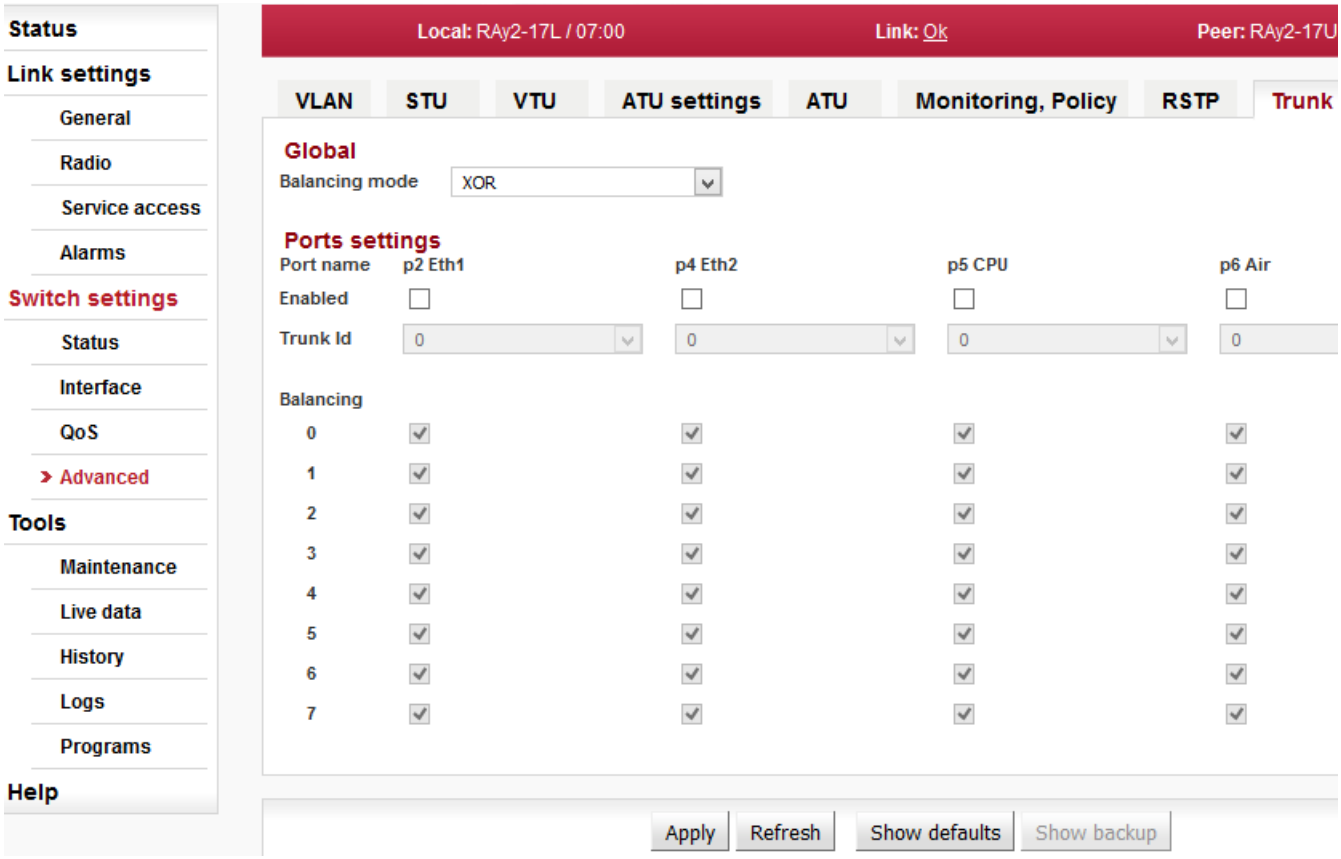


Fig. 7.42: Menu Switch settings - Advanced - Trunk

Port trunking is supported by the device using any combinations of ports. The ports that are to be associated with the trunk need to have all the port members' defined with the same *Trunk Id* and the *Enabled* parameter has to be enabled.

When a frame enters a Trunk Port its Source Address (SA) is learned with its association to the ingress port's TrunkID number. In this way the contents of the address database contain the same association with the frame's SA regardless of the link of the trunk the frame entered the switch.

When frames are routed back toward a trunk the frame will have its Destination Address (DA) found from the address database. If the frame's DA is unknown the frame will try to flood out all ports of the trunk (this is OK in so far as this will be fixed with load balancing). If the frame's DA is found, the entry will indicate mapping to a trunk and the entry's DPV bits will contain the TrunkID associated with this frame's DA. This TrunkID needs to be converted into a DPV (Destination Port Vector) that the rest of the switch can use. This is accomplished by accessing the Trunk Mapping table using the TrunkID that was in the ATU's entry.

Balancing mode Hash DA and SA for TrunkMask selection. Trunk load balancing is accomplished using the frame's DA and SA fields to access one of eight Trunk Masks. Two options are available:

- XOR — The lower 3 bits if the frame's DA and SA are XOR'ed together to select the TrunkMask to use.

hash	The hash computed for address table lookups is used for the Trunk-Mask selection. Use this parameter to reach better load balancing between the ports in the trunk.

Port name Identification of the internal switch port. The switch ports are connected to an external port or to an internal device (radio modem, management CPU).

Eth1	The external port (with RJ45 interface) labeled "ETH1+POE". Port 2.
Eth2	The external port (with SFP interface) labeled "ETH2". Port 4.
CPU	The internal port to management CPU. It is physical port number 5.
Air	The internal port to radio modem, i.e. link to the peer unit. Port 6.

Enabled When this parameter is enabled, the port is considered to be a member of a trunk with the *Trunk Id* defined below.

Trunk Id This parameter defines which trunk the port is to be associated with. All ports that are members of the same trunk must be assigned the same Trunk ID.

Balancing Trunk Mask bits.

7.6. Tools

7.6.1. Maintenance

Backup

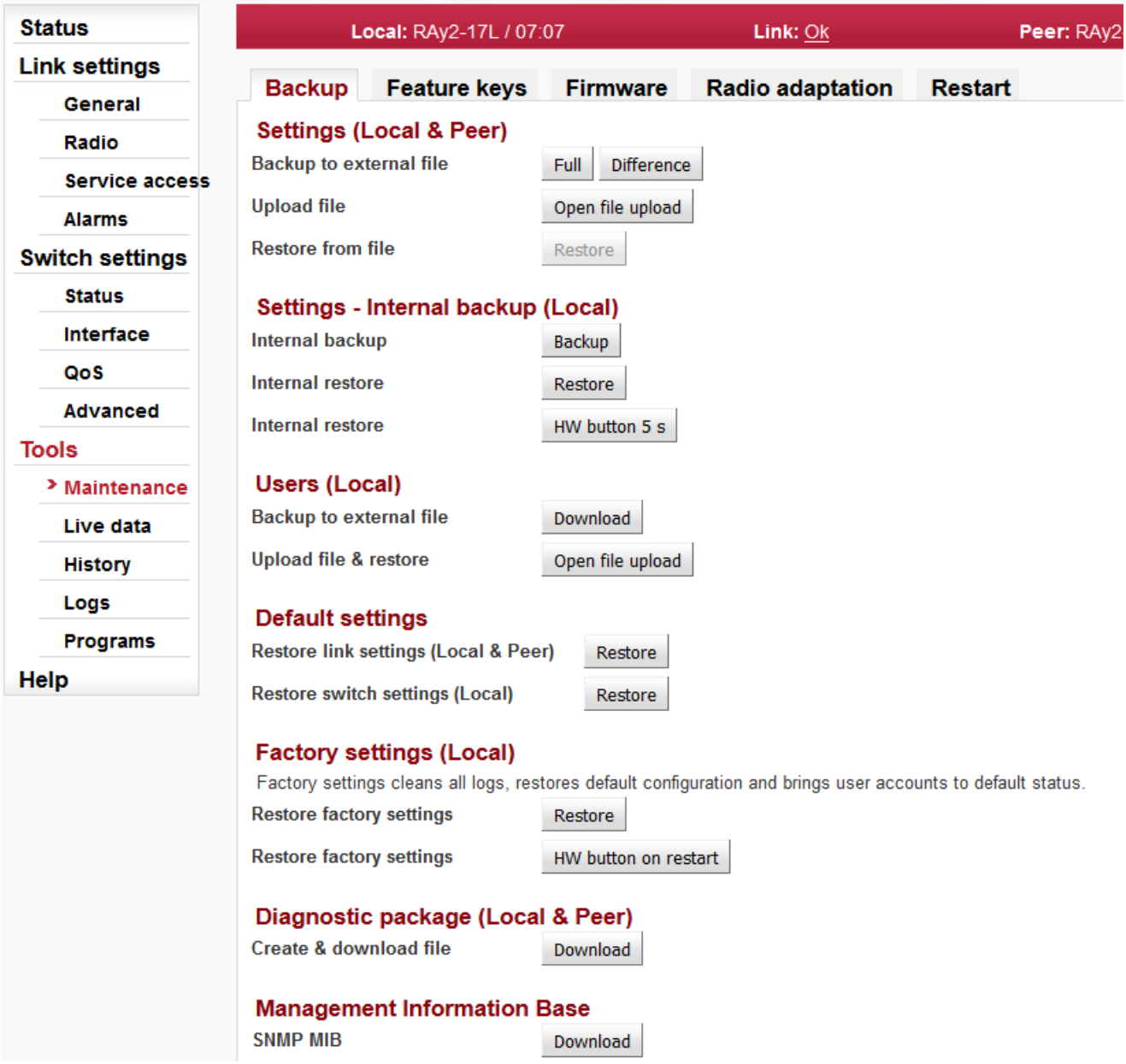


Fig. 7.43: Menu Tools - Backup

Settings (Local & Peer)	Saving and restoring unit configuration. User accounts are not affected by those functions.

Local	Peer	
O	O	Link
O	O	Switch
		Users

Backup to external file	Configuration is saved to backup file which is downloaded to management PC. The backup file name contains the date, time and RAy serial number as follows: `yyyyMMddhhmm_SN_cnf_backup.tgz`. It can be either a full configuration or a difference to the default configuration.
Upload file	Upload configuration from a backup file into buffer. The current unit configuration is not affected. The uploaded configuration can be displayed using *Show backup* button on particular configuration screens. The configuration of the entire unit can be restored (from this buffer) using *Restore* button below.
Restore from file	After the configuration backup file has been loaded into the unit buffer (using Upload button above), the whole unit configuration can be restored using *Restore* button.

Settings - Internal backup (Local)

It is possible to make a temporary backup of the unit configuration. The backup is stored directly in the unit FLASH memory.

L	P	
O		L
O		S
		U

	NOTE: The internal backup is deleted if factory settings or firmware upgrade are performed.
Internal backup	Make a temporary backup of the unit configuration locally in the unit FLASH memory.
Internal restore	Restore (from the unit FLASH memory) the temporary backup of the unit configuration.
Internal restore - HW button	The local temporary backup of the unit configuration can be restored using the hardware button. The HW button is located next to the DC connector within the port marked "P". The rollback and reboot functions are suppressed while restoring from internal backup. All changes are applied immediately. Should the time zone be changed, the unit has to be restarted for changes to take effect. Press the HW button for the required time interval of 5 seconds. The button being pressed is confirmed by the Status LED flashing green. After the 5 seconds guard time, the unit restores to customer settings.

Users (Local)

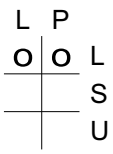
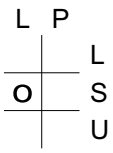
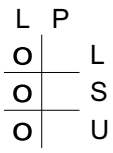
Saving and restoring user accounts.

L	P	
		L
		S
O		U

Backup to external file	Backup local unit user accounts to an external file. The file is downloaded to management PC. NOTE: The "super" user privileges are necessary to be able to perform this action.
Upload file & restore	Restoring user accounts from an external backup file.

Default settings

Applying default values to configuration parameters.

	Restore link settings (Local & Peer)	Whole set of parameters from the *Link settings* menu tree is affected.
	Restore switch settings (Local)	Whole set of parameters from the *Switch settings* menu tree is affected.
Factory settings (Local) 		WARNING: Using the factory settings function will revert the unit to its original state. All configuration items, user accounts, measured values and system messages (logs) will be irreversibly deleted. WARNING: This task takes a few minutes to complete. Do not interrupt the power supply during the operation.
	Restore factory settings	Applying Factory settings to Local unit. The unit reboots itself after applying all changes.
	Restore factory settings - HW button	It is possible to bring the unit to Factory settings by holding the hardware button depressed during unit's boot. The HW button is located next to the DC connector within the port marked "P". Disconnect the power supply from the unit. Keep the HW button depressed while reconnecting the power. The LED marked SYS starts to flash red after a few seconds. Keep the HW button pressed another 5 seconds until the red status LED stops flashing. The unit's boot up sequence continues and Factory settings are applied. Should the HW button be released when the status LED is in the red flashing phase (but before the 5 s guard time), the unit stays in Service mode. Please, leave this mode by rebooting the unit.
Diagnostic package (Local & Peer)	To facilitate communication with the technical support you can create an archive file with detailed information about the unit. If connection with Peer unit is active the diagnostic information from both units are saved.	
	Create & download file	Saving a file with information about the unit (Local and Peer). NOTE: This task takes a few minutes to complete.
Management Information Base	SNMP MIB	Provides Management Information Base table.

Feature keys

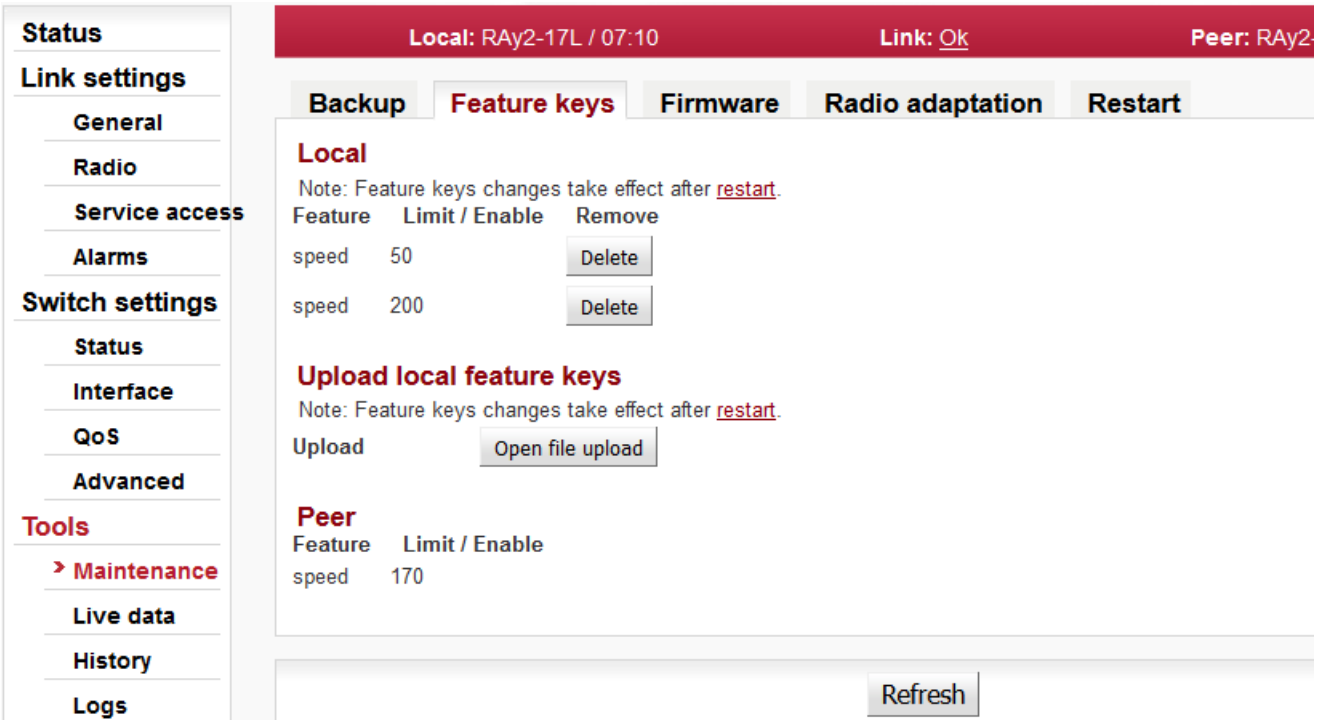


Fig. 7.44: Menu Tools - Feature keys

The sub-set of RAy parameters is affected by use of Feature keys.

The feature keys limiting data transfer speed [Mbps] are now available. Speed of the transferred data is determined by a combination of the radio channel bandwidth (parameter Bandwidth [MHz]) and modulation order (parameter TX modulation). The Feature key limiting the data transfer speed enables only certain combinations of the channel bandwidth and modulation order to get the data transfer speed according to the Feature key. The data transfer speed is typically slightly higher than declared.

When installed, the Feature key is activated after the unit restart. The unit can be restarted using the Tools – Maintenance – Restart. Choose the Restart mode – warm.

Feature — Name of the function controlled by the Feature key.

Here are listed the keys used in both units. Feature keys of the Peer unit only, are displayed. They can be neither added, nor deleted. To be able to manipulate the Feature keys, it is necessary to access directly the management system of the relevant unit - use the IP address of the relevant unit.

Limit — The numeric value set by the key.

Remove — The specific Feature key can be deleted using the Delete button. The parameters controlled by this Feature key are reset to their default values after the unit restart. NOTE: The link radio parameters can be changed subsequently (e.g. to a different operating frequency)!

Upload — Feature keys are installed into the unit from the binary files.
NOTE: Use the file as it is (do not unpack).

Open file upload - Dialog for the Feature key binary file selection is open.

The Feature key is activated after the unit restart.

Firmware

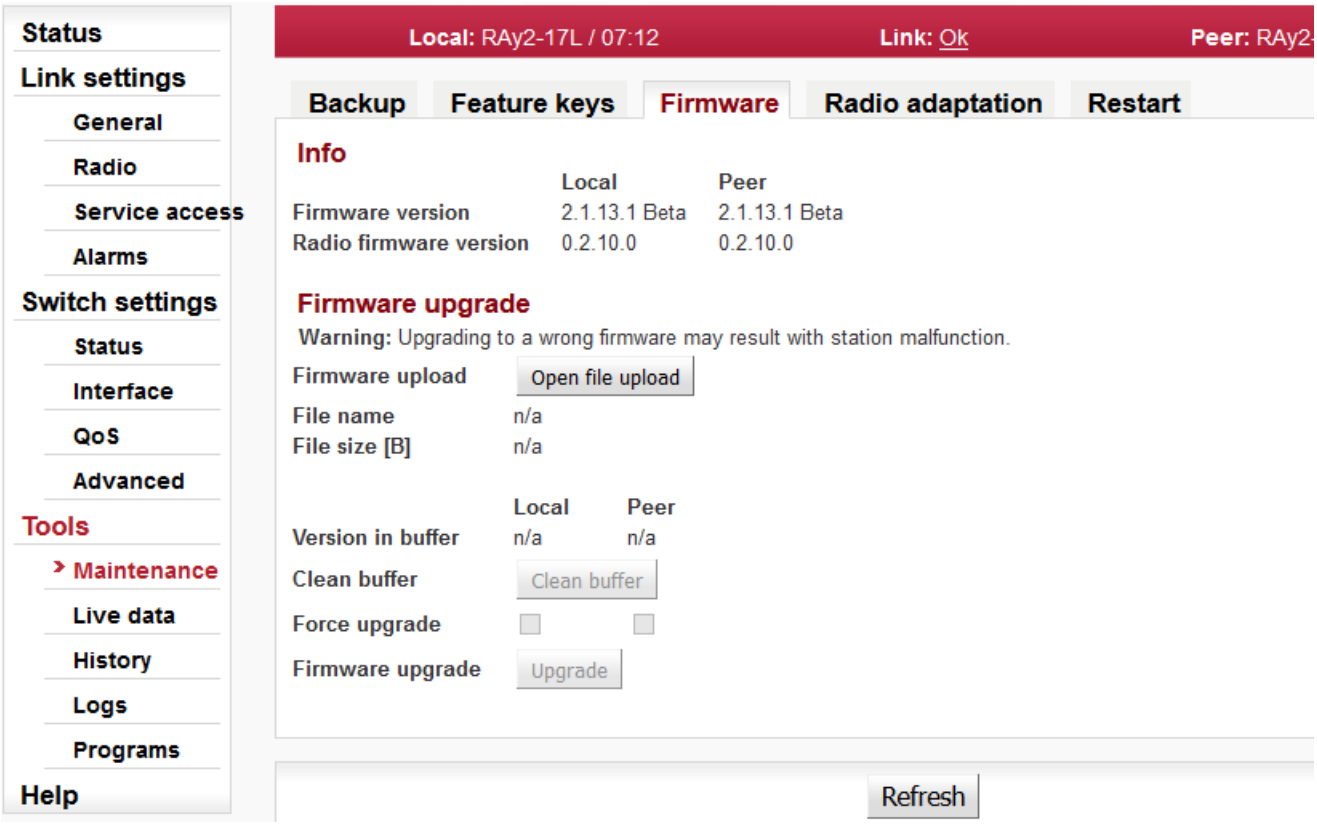


Fig. 7.45: Menu Tools - Firmware

If a new firmware version is released for the given microwave link type, you can upload it to your RAy units.

Info

Firmware version Information about the current firmware package version on Local and Peer unit.

Radio firmware version Information about the radio board current firmware version on Local and Peer unit.

Radio configuration version Radio board calibration data format version.

Hardware version Information about the HW version of the modem board.

Radio hardware version Information about the HW version of the radio board.

Firmware upgrade

Firmware upload Open file upload - opens a dialog for uploading firmware package to the unit buffer. Only after firmware has been prepared in the buffer, can you perform the actual upgrade.
NOTE: Use the file as it is (do not unpack).

File name Name of the uploaded firmware file.

File size [B] Size of the uploaded firmware file.

Version in buffer Information about firmware version prepared in the buffer for installation into the unit (Local, Peer). This firmware must first be prepared in the Firmware upload section (see above).

Clean buffer You can use the Clean buffer button to delete prepared firmware package in the buffer.

Force upgrade Force mode blocks all safety and compatibility checks and probably bricks your unit.
You should not use force mode until instructed to do so by the technical support.

Upgrade Use the Upgrade button to perform the firmware installation.

Warning

Installing the firmware takes several minutes (about 3 minutes). During this time, transmission of user data is interrupted. Do not interrupt the power supply during firmware installation!

Radio adaptation

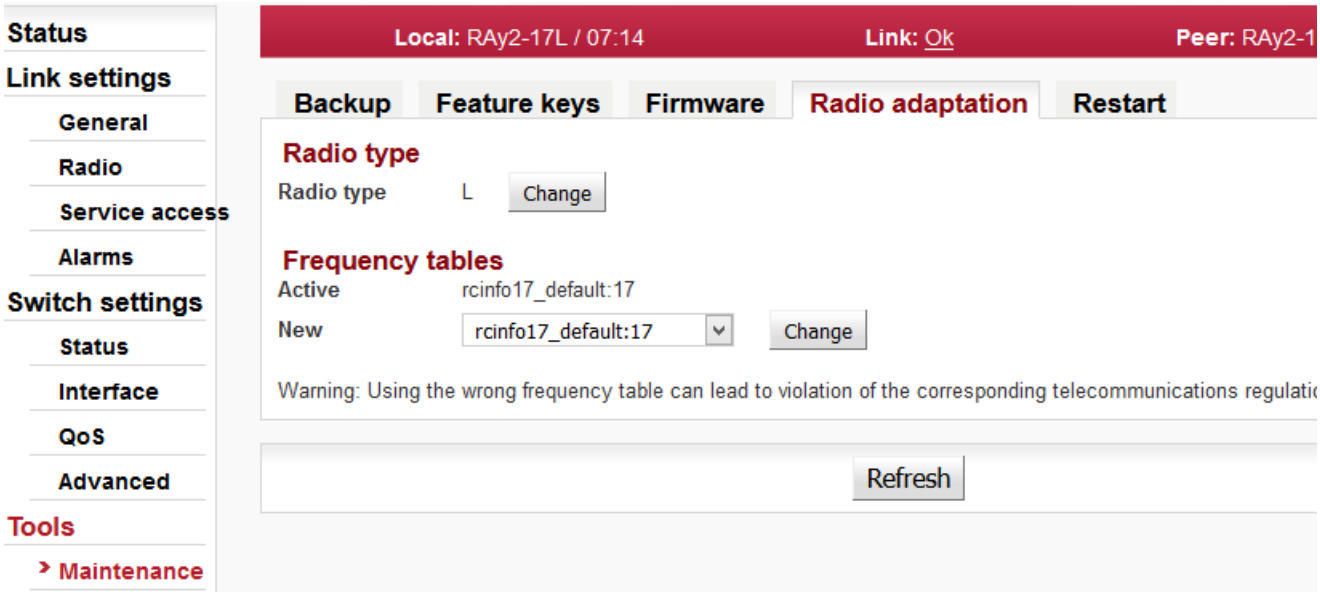


Fig. 7.46: Menu Tools - Radio adaptation

Radio type

IMPORTANT: Applies only for RAy2-17 and RAy2-24 links.

Hardware of these links is universal for the entire frequency band. To facilitate the configuration of radio parameters, units are coded for L (Lower) and U (Upper) part of the band. L or U band assignment can be modified.

Radio type — Radio unit type: L (Lower) or U (Upper) part of the frequency band. Use the Change button to change the radio type.

WARNING: When the radio type is changed, the *Link settings* menu parameters of each unit are **reset to default** values except login / password details.

Frequency tables

The microwave link contains one or more frequency tables (called rcinfo). These tables contain the following information:

List of available bandwidths and modulations.

Assignment of frequencies to the channels and the names of these channels. These channels are used to configure radio parameters of the link (see screen *Link settings – Radio*).

Default values of radio parameters.

A set of radio parameters, needed for the ATPC operation.

Active — Name of the currently used frequency table.

New — Select a new frequency table. Available tables are displayed in format <name:version>. Use the Change button to change the table.

WARNING: Using the wrong frequency table can lead to violation of the corresponding telecommunications regulations.

Restart

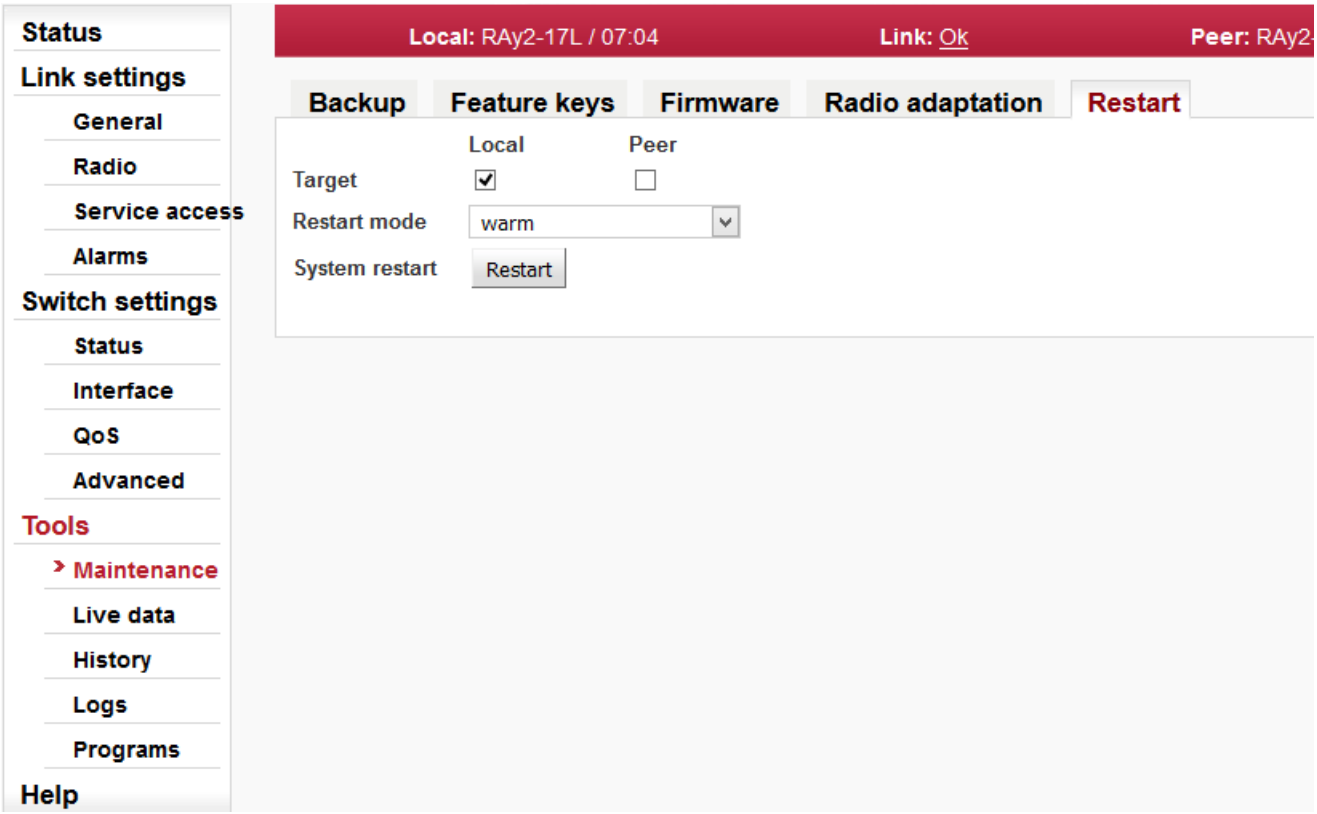


Fig. 7.47: Menu Tools - Restart

Target Restart of selected unit, Local or Peer.

Restart mode

Warm	Reboot management system.
Cold	Restart the whole station as if power was removed.

System restart Performs the selected restart.

7.6.2. Live data

Bar indicators

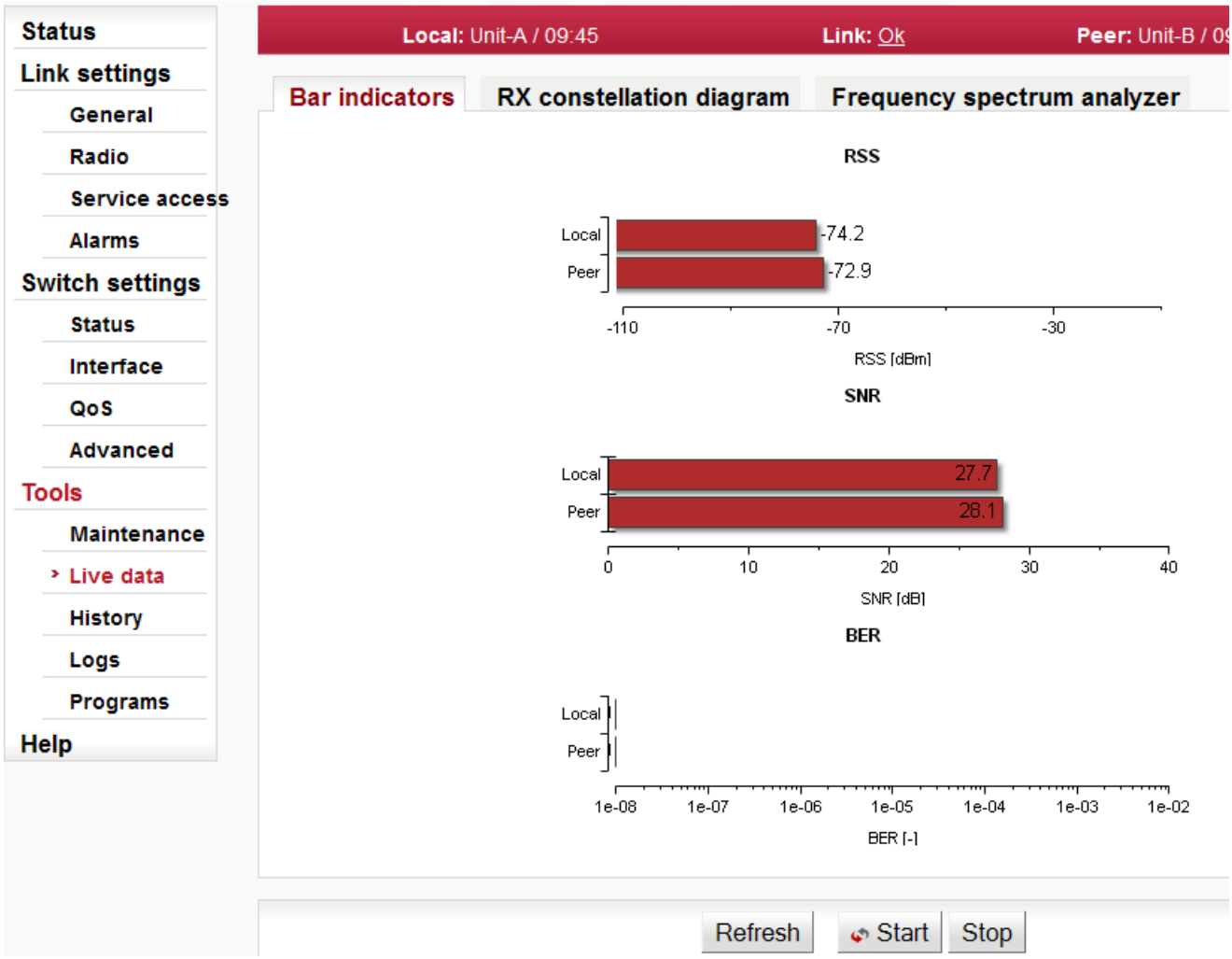


Fig. 7.48: Menu Tools - Bar indicators

Graphical indication of BER, SNR and RSS.

Refresh	One-time update of displayed values.
Start, Stop	Use the Start button to start automatic update of displayed values with a period of 1 second. Use the Stop button to stop it.

RX constellation diagram

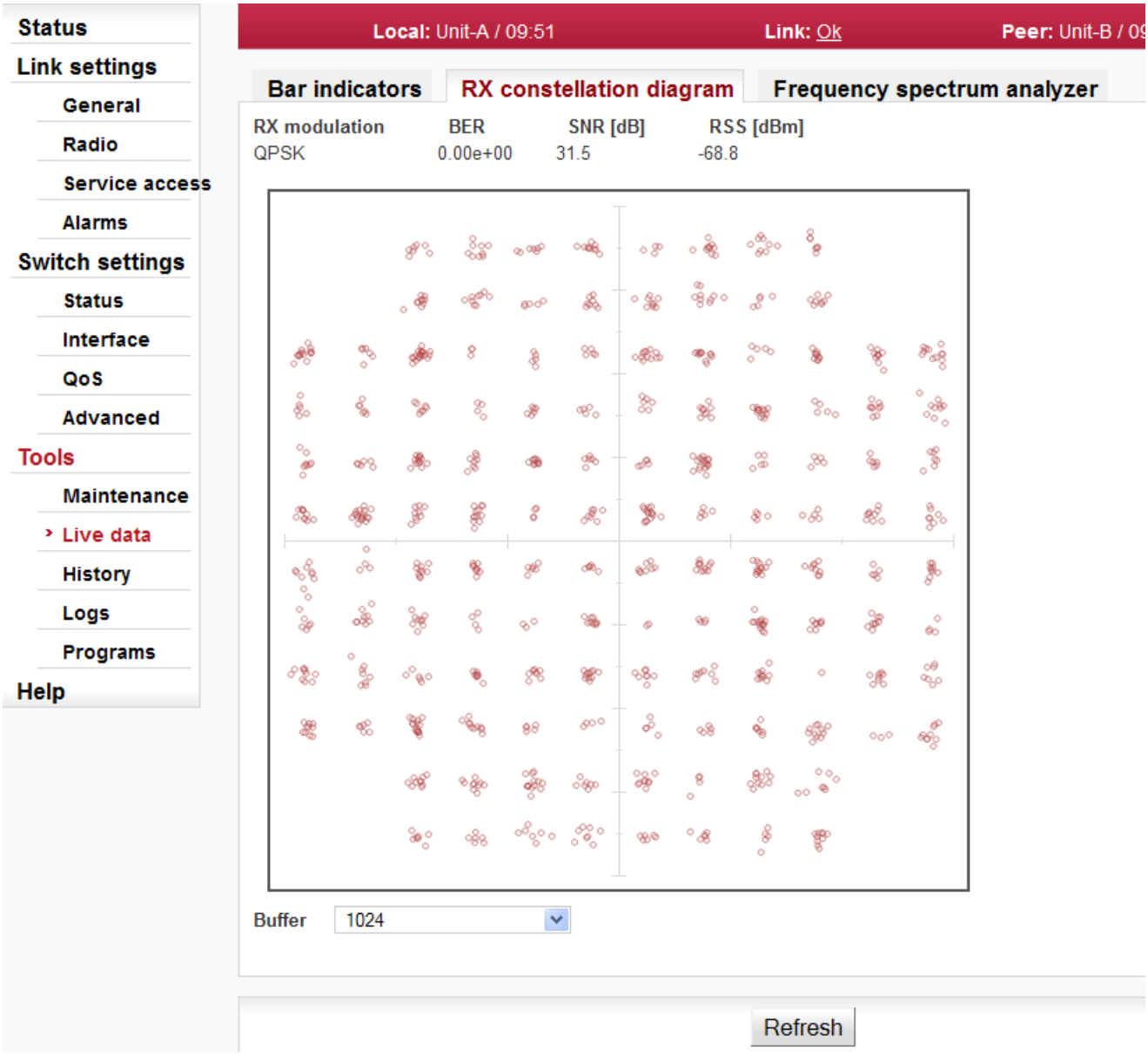


Fig. 7.49: Menu Tools - RX constellation

Constellation diagram shows the quality of received signal.

RX modulation	Modulation level of RX channel.
Buffer	Number of plotted points.
Refresh	One-time update of diagram.

Frequency spectrum analyzer

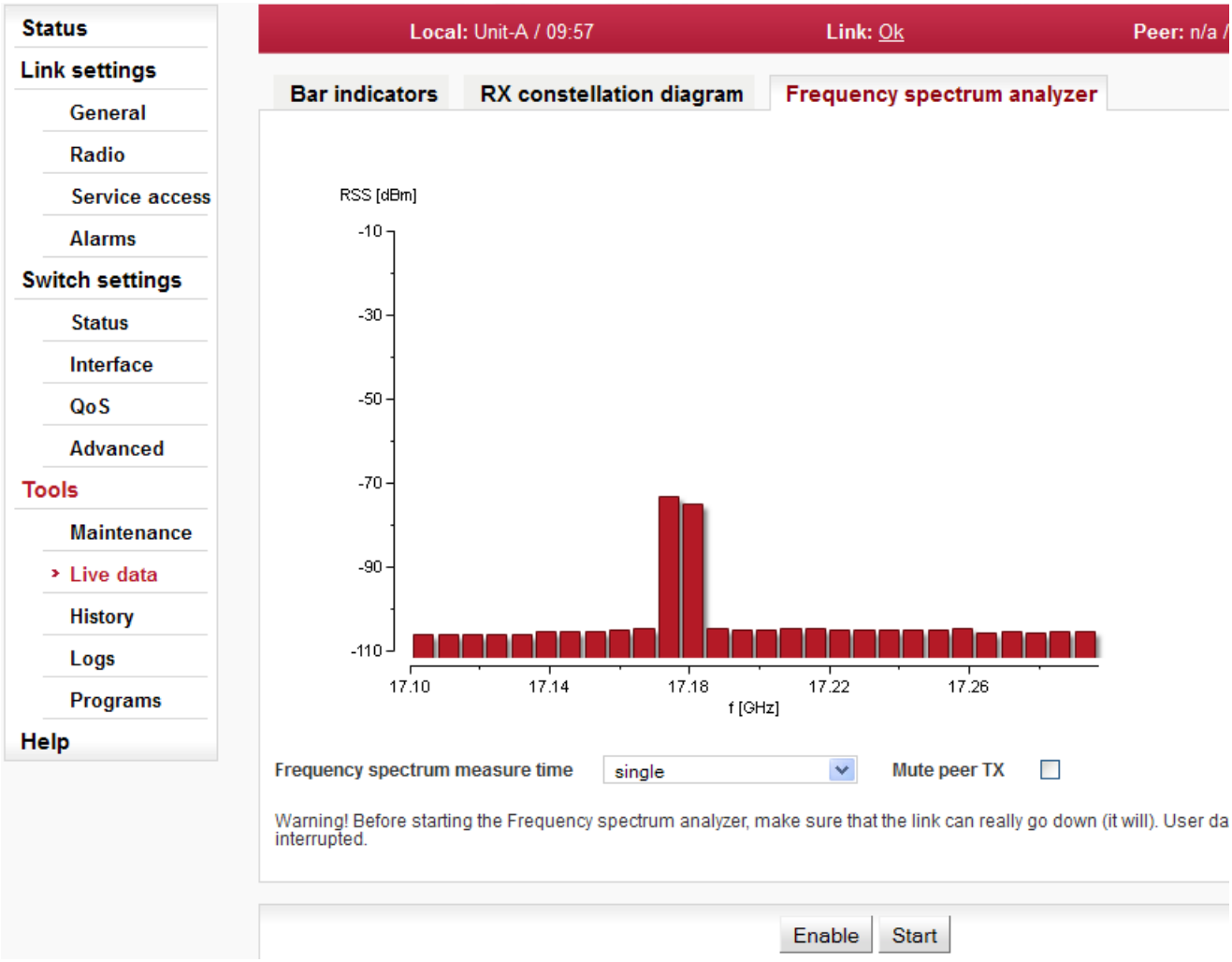


Fig. 7.50: Menu Tools - Frequency analyzer

A very useful tool for identifying in-band interference and locating a free channel. It is not a full-blown spectrum analyzer as it scans the spectrum with 7MHz channel resolution. The accuracy of measured results is given by the accuracy of measuring RSS.

Warning

Running spectrum measurement causes interruption of user data flow between stations!

Enable	Opening analyzer functions.
Start	Interrupts communication on the link and starts scanning frequencies in the band.
Spectrum measure time	Selection of measurement length in range: single sweep … up to 15 min
Mute peer TX	The deactivation of Peer station transmission during measurement.

After using the analyzer visit any of the *Link menu* settings and select *Refresh*. This restores the configuration connection (message Peer: n/a).

7.6.3. History

The unit continuously stores information about the values of important variables. Stored values can be viewed using three methods - Thumbnails, Viewer and Data

Thumbnails

Preview all values for the last 24 hours. Click on a thumbnail to open the viewer with a chart.

Fig. 7.51: Menu Tools - History - Thumbnails

Temperature	Instantaneous value of temperature inside the unit. Measured on the modem board. Temperature of radio board is available via SNMP.

Voltage	Instantaneous value of unit supply voltage.
RSS	Received signal strength.
SNR	Signal-to-noise ratio of the received signal.
BER	Instantaneous bit error rate on link.
Net bitrate	Instantaneous transmission capacity.
Eth1, Eth2 in throughput	Instantaneous speed (20s average) of incoming user data on the user Ethernet port.
Eth1, Eth2 out throughput	Instantaneous speed (20s average) of outgoing user data on the user Ethernet port.
TX power	Instantaneous value of transmission power.

Viewer

Detailed graphical view of one or two selected values for the given interval. You can choose to view data from Local or Peer or both.

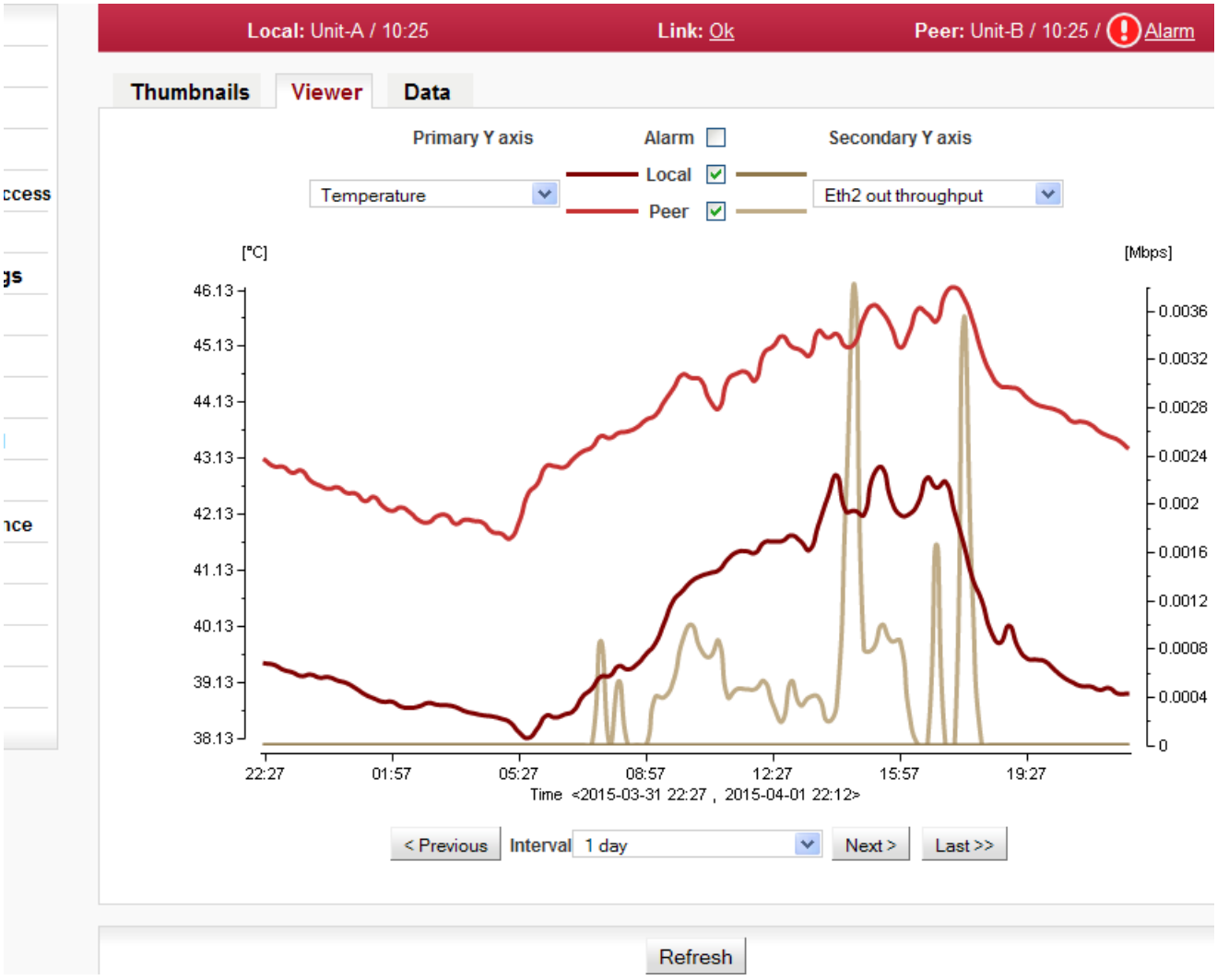


Fig. 7.52: Menu Tools - History - Viewer

The values are saved in the following resolutions and history lengths:

Resolution 1 minute, length of history 7 days

Resolution 15 minutes, length of history 30 days

Resolution 1 day, length of history about 180 days

Interval

Selecting width of interval to be displayed. Based on the interval width, data is displayed in a suitable grid: Up to 3 hours at one minute. Up to 4 days at 15 minutes. For longer intervals at one day.

Interval	Resolution	History
1 hour - 3 hours	1 minute	7 days
6 hours - 4 days	15 minutes	30 days
1 week - 6 months	1 day	180 days

More options:

Previous	Move by one width of selected interval towards older values.
Next	Move by one width of selected interval towards newer values.
Last	Move to the newest values.

Primary Y axis

Selecting one of the observed values:

Temperature, Voltage, RSS, SNR, BER, Net bitrate, Ethernet in throughput, Ethernet out throughput, TX power

Secondary Y axis

Selecting a second value:

None

Temperature, Voltage, RSS, SNR, BER, Net bitrate, Ethernet in throughput, Ethernet out throughput, TX power

Alarm

Enables the display of alarms, if there were any.

Data

Numerical view of all values

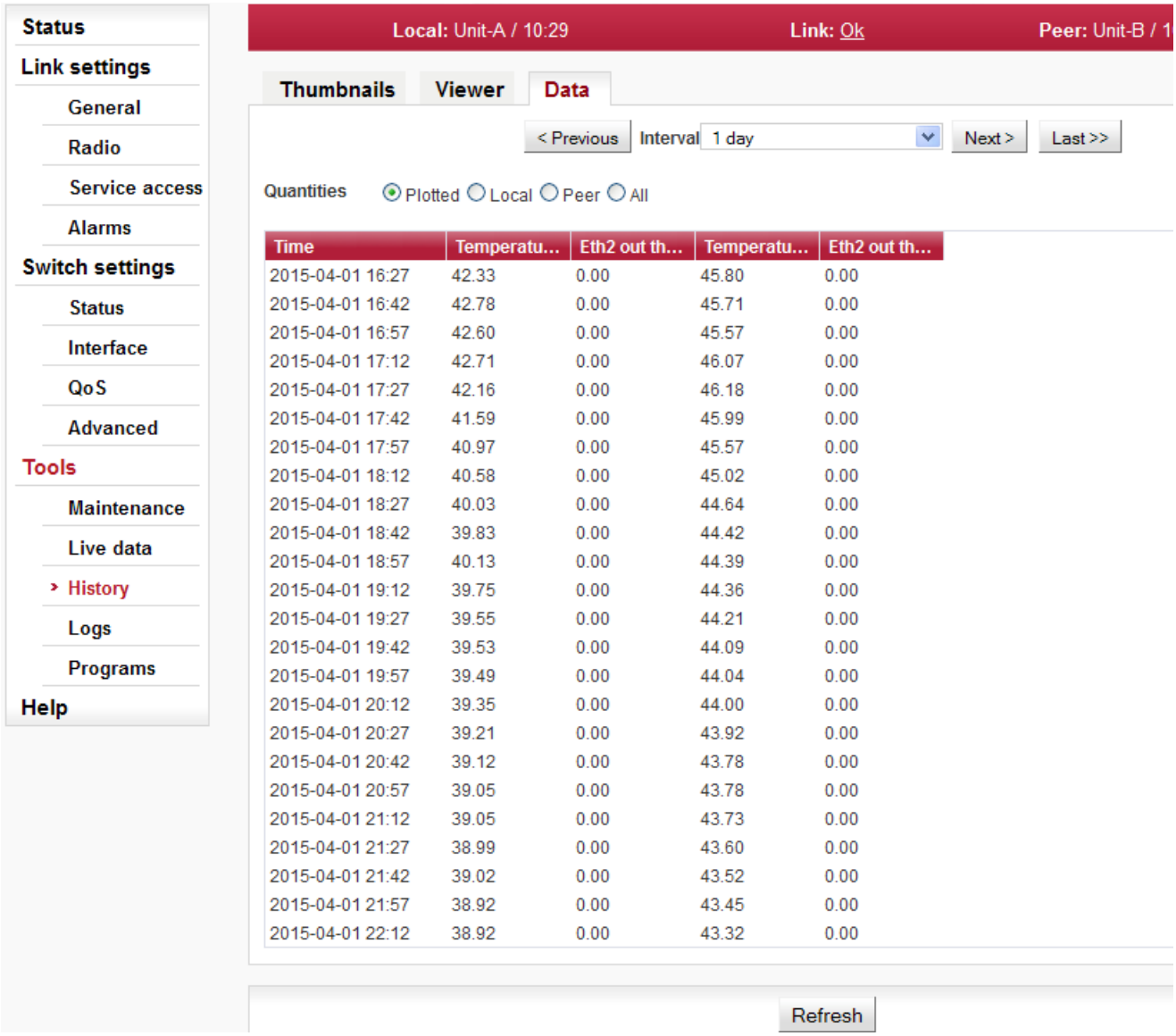


Fig. 7.53: Menu Tools - History - Data

Quantities Detailed graphical view of values for selected interval.

Plotted - Shows only the values that are selected for the graph.

Local, Peer, All - Shows all logged values. Filtering of values from local, remote or both.

7.6.4. Logs

Shows internal unit logs. Individual tabs allow total or filtered view.

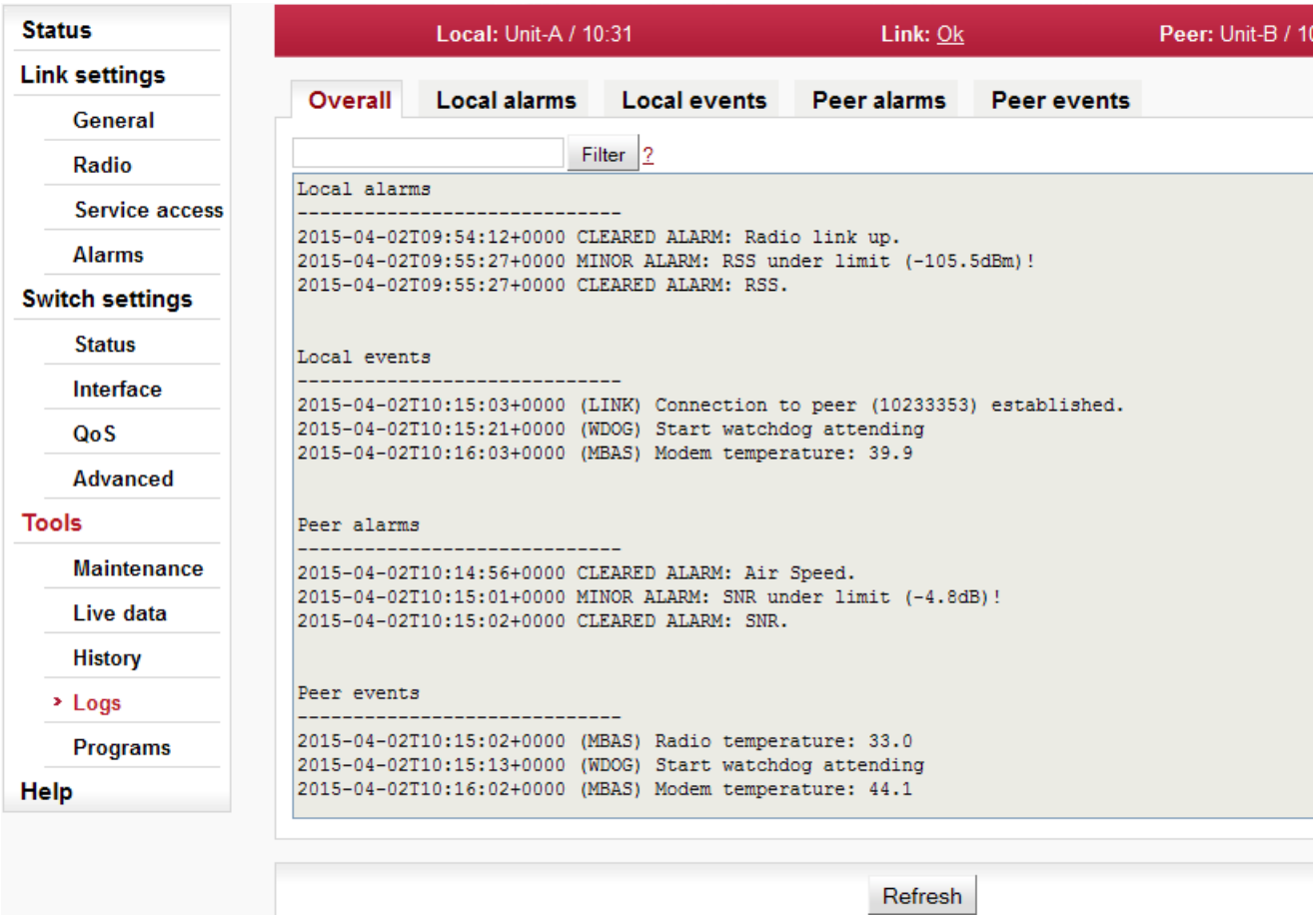


Fig. 7.54: Menu Tools - Logs

When you first open the screen, it is necessary to start browsing logs by pressing the Refresh button.

Maximum length of displayed logs is 250 entries. If you need to display longer history, use of CLI interface is needed.

Overall	Displays the last 3 records from all types of logs.
Local alarms, Peer alarms	Alarms from Local or Peer unit.
Local events, Peer events	Events from Local or Peer unit.
Filter	Listings of all logs can be filtered. You can enter text in the upper left corner window for filtering listings. For example, you want to know when the configuration of the unit was modified: On the Local events screen, enter *Configuration* and hit Enter. You can use plain text or regular expressions for filtering (JavaScript format).

7.6.5. Programs

Ping

The Ping tool allows sending ICMP pings to a selected address

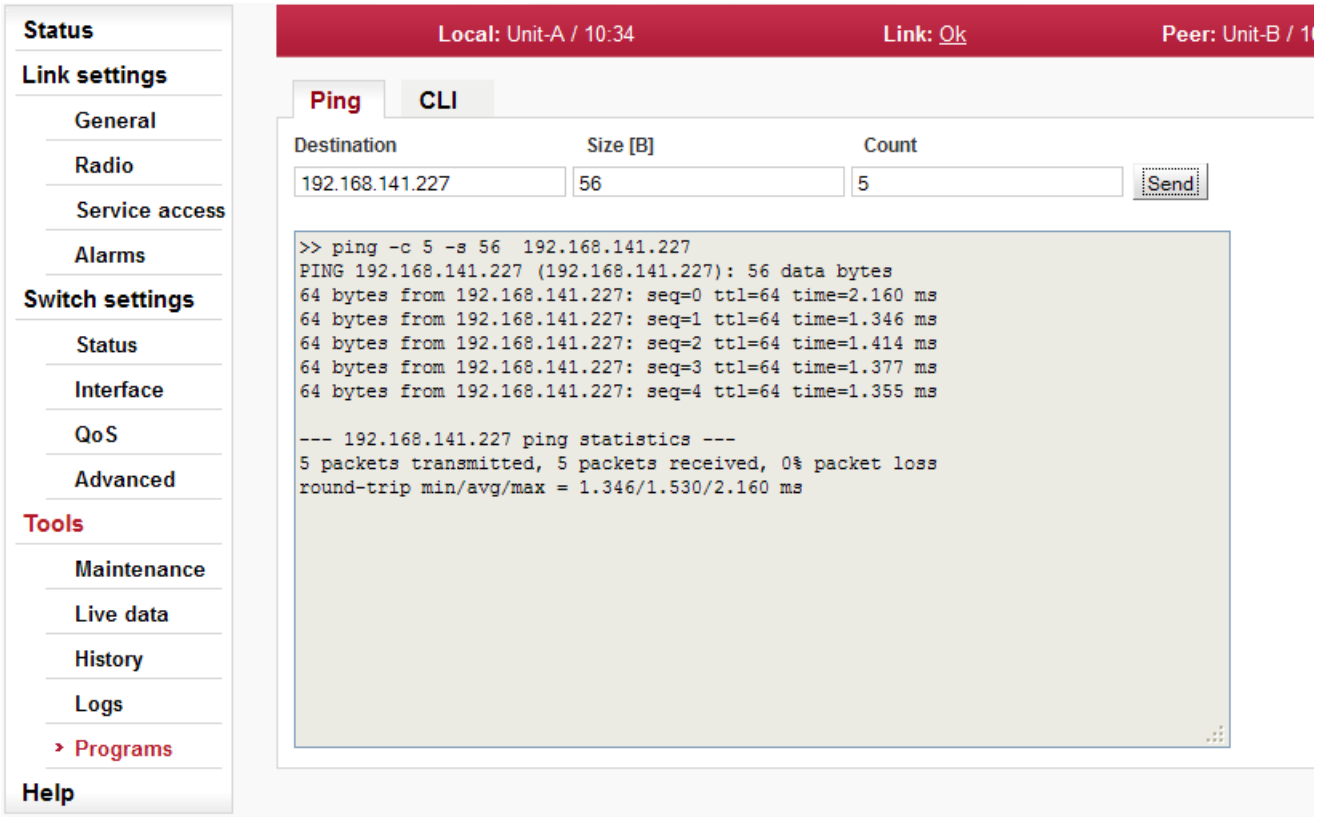


Fig. 7.55: Menu Tools - Programs - Ping

Start the test by clicking on *Send*. The result is displayed in the text window.

Destination	Destination address in dotted decimal notation. The default address 127.0.0.1 is the localhost address - i.e. the unit itself.
Size [B]	Length of sent data 7 to 1500 bytes, 8 bytes of the header will be added.
Count	Number of sent pings. The period for sending pings is constant: 1000 ms.

CLI

Web interface for executing non-interactive scripts and programs.

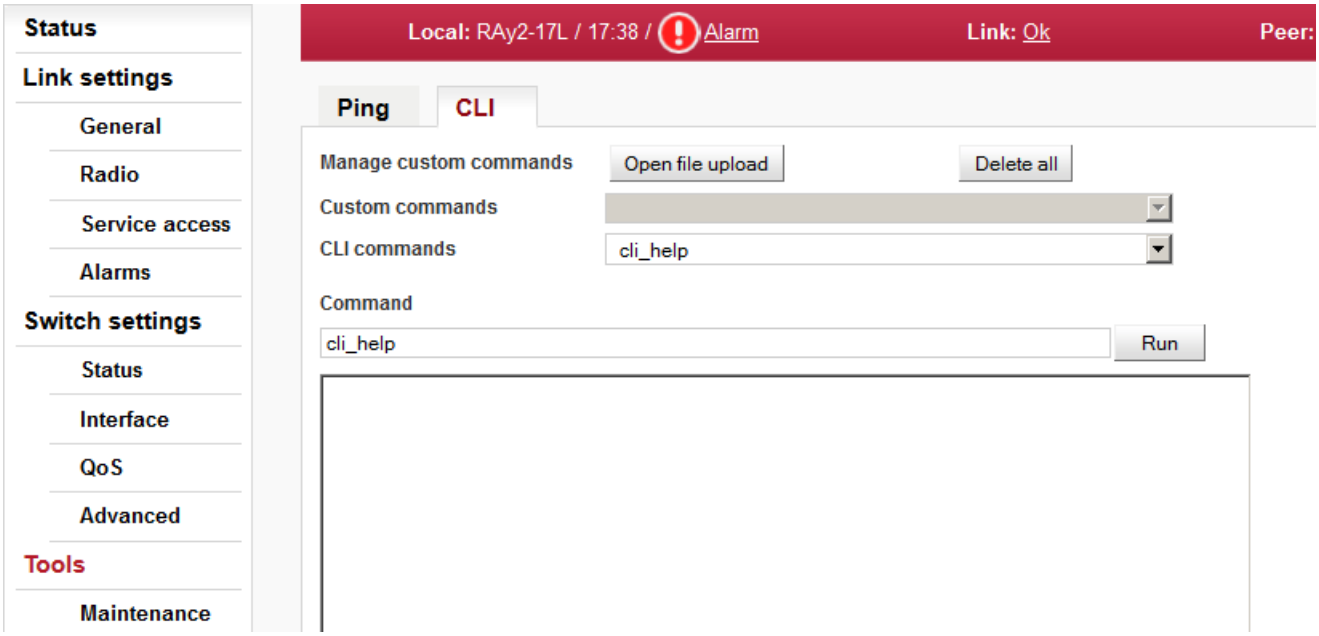


Fig. 7.56: Menu Tools - Programs - CLI

Manage custom commands

Using "Open file upload"/"upload" the user can upload scripts to the unit. The uploaded file can be either a single shell script with extension .sh (e.g. my_script.sh) or package with multiple scripts with extension .tar.gz or .tgz created using tar.

"Delete all" removes all custom scripts from the unit.

Custom scripts are located in /home/shared/bin.

Custom commands

A custom script can be selected here and initial comments/help is shown.

CLI commands

A CLI command can be selected here. You can use cli_help for listing all CLI commands or <command> --help to obtain detailed help on a selected command.

Command

Command line for writing commands with parameters. You can use any non-interactive program/script according to your permissions.

Format of custom scripts

Custom scripts must be a shell script with preamble #!/bin/sh and extension sh.

Blocks of lines beginning with the comment sign (#) after preamble are considered to be help and are listed when the script is selected in the web interface.

Scripts should not be interactive as there is no possibility to send a response from the web interface. All script options should be implemented as parameters.

Syntax should be valid for interpret shell ash from BusyBox v1.20.1.

Example of custom script

```
#!/bin/sh
#script checkes if service with the same name or vid already exists
#if not creates a new entry in VTU with given VID
#
#  input parameters:
#      service_name - name of the new service
#      VID - vid of the new service
#
#  return values:
#      0 - ok
#      3 - bad parameter
#      5 - service already exists
#      6 - there already exists an entry with given VID
#     42 - other error

D42_NAME="$1"
D42_VID="$2"

D42N="service_data42"

error()
{
        echo "$D42N: Error: $*" >&2
}

info()
{
        echo "$D42N: $*" >&2
}

die()
{
        error "$*"
        exit 42 #error
}

# basic check if not empty
if [ -z "$D42_NAME" ]; then
        error "Bad service name"
        exit 3
fi
if [ -z "$D42_VID" ]; then
        error "Bad service VID"
        exit 3
fi

D42_FOUND=$(cli_nw_get --vtu all | grep "$D42_NAME")
if [ -n "$D42_FOUND" ]; then
        error "Service(s) with name $D42_NAME found"
        echo $D42_FOUND
        exit 5
fi
```

```
D42_VALID=$(cli_nw_get --vtu "$D42_VID" | sed -n 's/^valid=\(.\+\)$/\1/p')
if [ "pre_$D42_VALID" = "pre_true" ]; then
        error "VID $D42_VID is used"
        cli_nw_get --vtu "$D42_VID"
        exit 6
fi

D42_VALID=$(cli_nw_get --stu 1 | sed -n 's/^valid=\(.\+\)$/\1/p')
if [ "pre_$D42_VALID" = "pre_false" ]; then
        info "Creating STU entry with SID=1"
        cli_nw_set --stu 1 'label="D42_auto", port_state=["disabled", "disabled", ▶
"forwarding", "disabled", "disabled", "forwarding", "forwarding"]'
        if [ $? -ne 0 ]; then
                die "Failed to create STU entry"
        fi
fi

info "Creating service \"$D42_NAME\" with VID=$D42_VID"
cli_nw_set --vtu "$D42_VID" label="$D42_NAME" 'fid=0, sid=1, pri_override=true, priority=5, ▶
policy=false, member_tag=["unmodify", "unmodify", "tag", "unmodify", "not_member", ▶
"not_member", "unmodify"]'
if [ $? -ne 0 ]; then
        die "Failed to create service \"$D42_NAME\" with VID=$D42_VID"
fi
```

7.7. Help

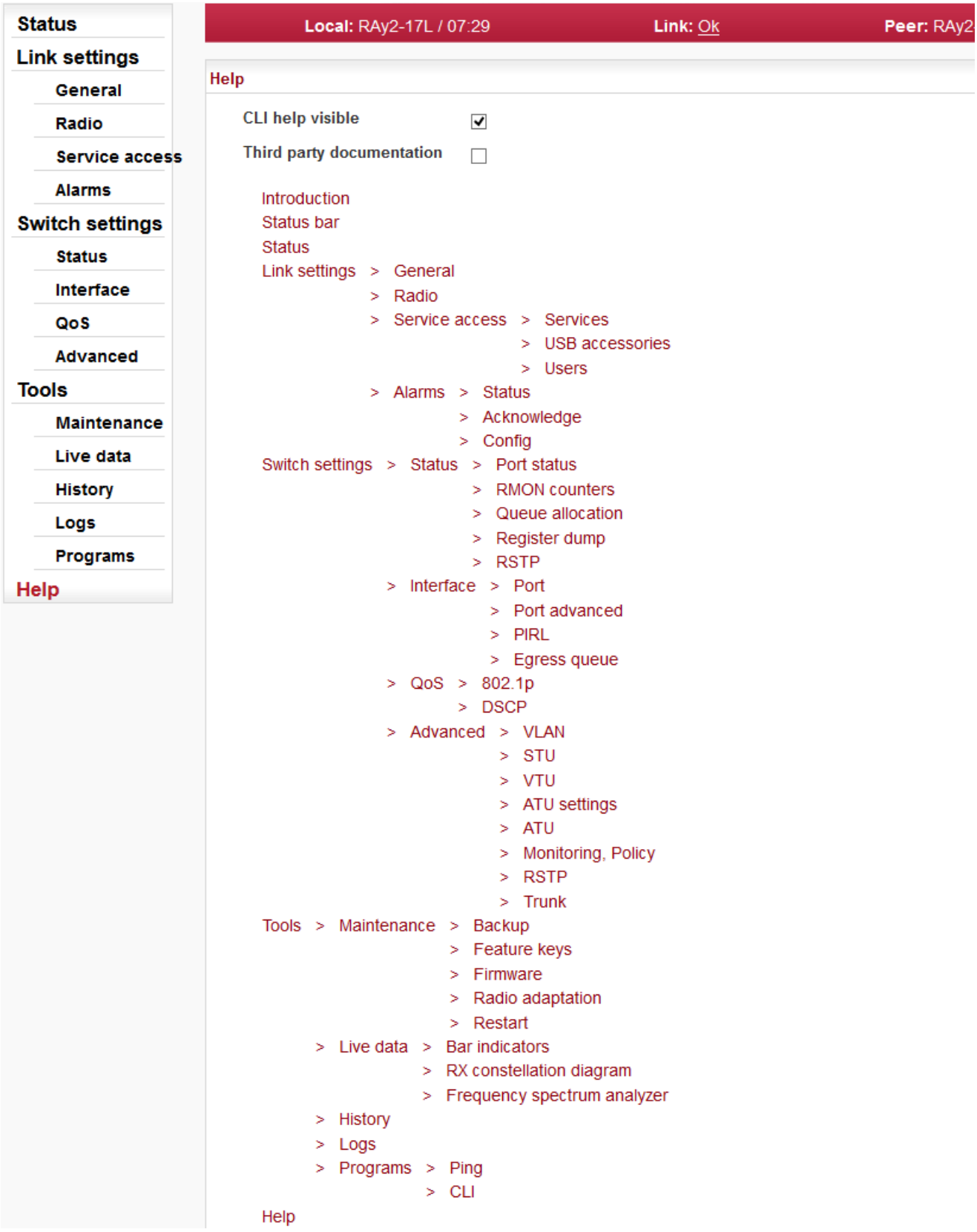


Fig. 7.57: Help menu

Help from Help menu

The Help screen displays contents of the embedded help. The help text is displayed in the whole configuration window. The text structure corresponds to individual configuration screens. Every item of this Help opens the specific help menu.

CLI help visible	Allows displaying of the CLI help with examples.
Third party documentation	Allows displaying references to the third party documentation (e.g. internal switch documentation).

Help from configuration menu

Clicking the **name of the specific parameter** in the configuration menu brings up the help belonging to this parameter. The help text is displayed in the pop up window:

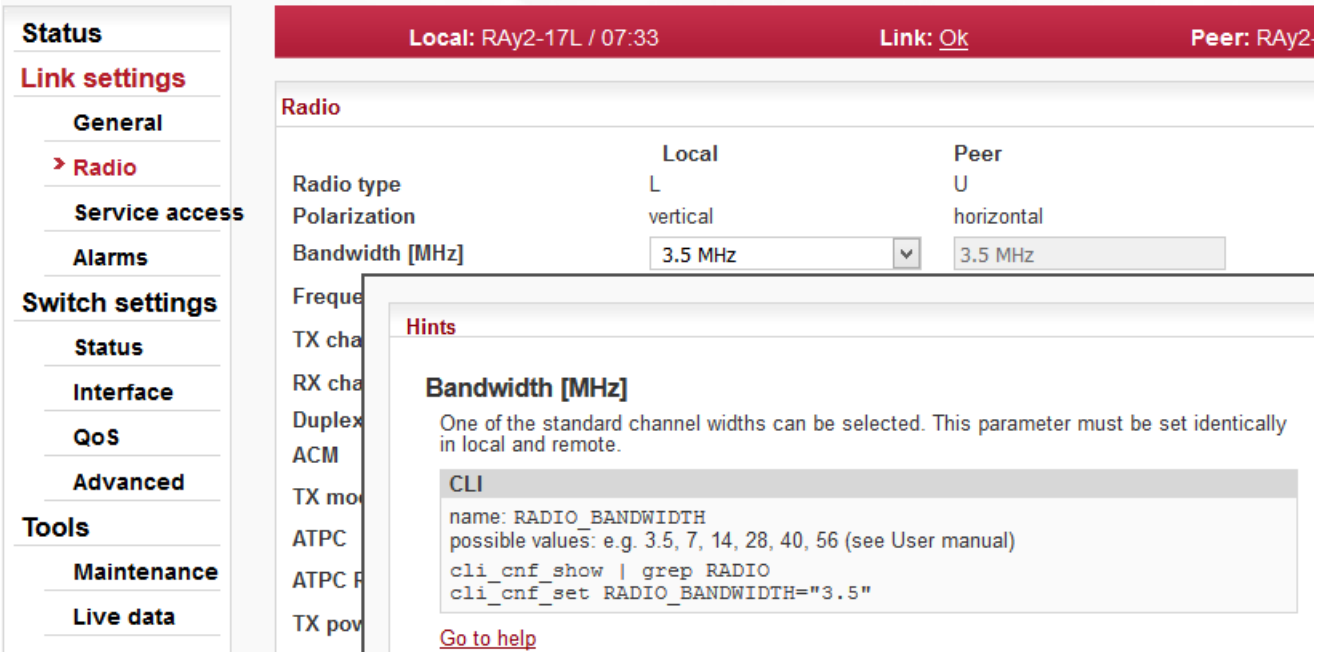


Fig. 7.58: Parameter help

There is a **Go to help** link within the help text. It displays the whole configuration menu help:

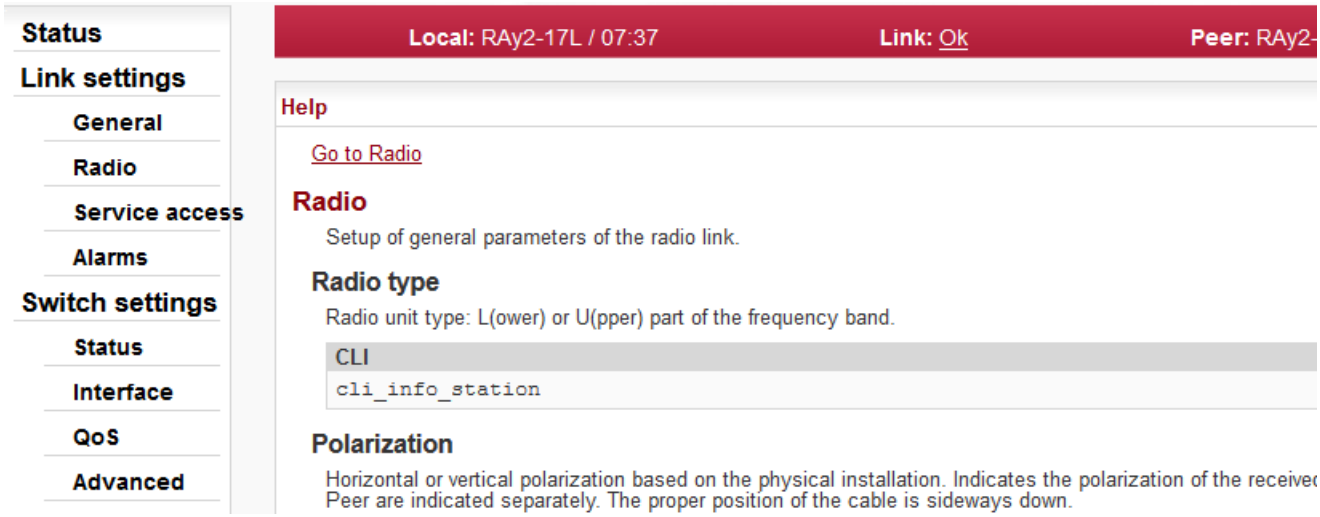


Fig. 7.59: Configuration menu help

There is a link on each help screen which points to the respective configuration screen.

Clicking the **question mark** icon in the upper right corner of the configuration screen brings a summary help for the configuration screen in the pop up window:

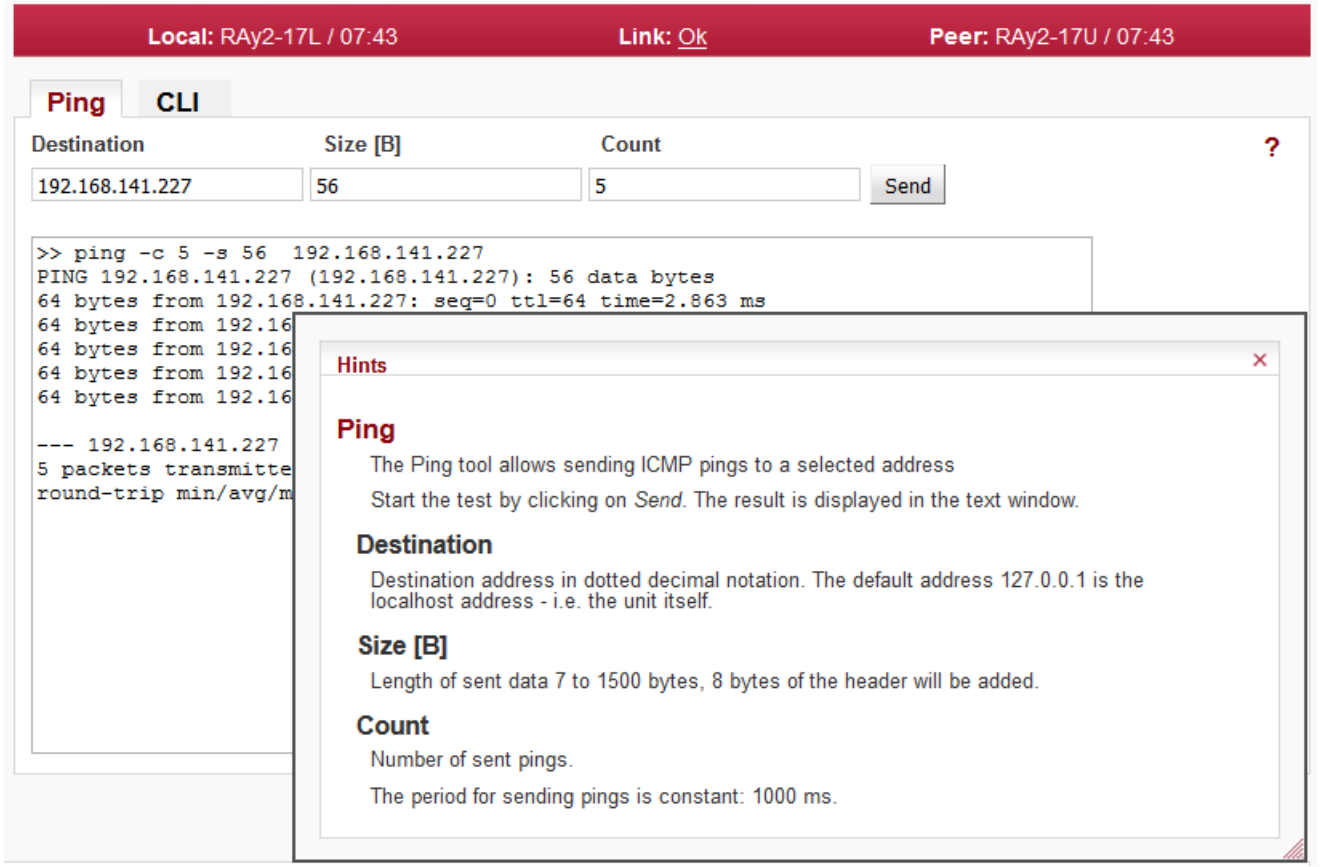


Fig. 7.60: Summary help

The Help window can be moved by dragging the *Hints* bar. Resize it by dragging the bottom corner.

8. Command Line Interface

The Command Line Interface (CLI) provides an alternative to HTTPS access. CLI allows you to work in a text regime interface using an ssh (putty) or telnet client.

8.1. Connection via CLI

8.1.1. Telnet

Use the **telnet** client to connect to the unit with service IP address 192.168.169.169. Type this in the command prompt:

```
telnet 192.168.169.169
```

Then use the username and password from the menu `Service access/Users` for https access (by default `admin, admin`). This works if `Service access/Services/Telnet` is checked in https access.

8.1.2. Putty

Connection using **putty client**. Type this into the Host Name (or IP address) field:

```
admin@192.168.169.169
```

Click Open. Then enter the password `admin`. This procedure (without key) is subject to selection `Service access/Services/SSH` **on** in https access.

If you own the private key part, then you do not need a password. In putty, continue by selecting `Connection/SSH/Auth` and selecting path to file with key e.g. `key.ppk`. Use `Session/Logging` to save the putty configuration. To access the unit via CLI simply select the connection in putty and click Open.

8.1.3. SSH

Connection using client **ssh** in Linux.

```
ssh admin@192.168.169.169 -i key
```

If you know the password and it is enabled in `Service access/Services/SSH` **onlykey** in https access, you can skip the key and use password in the next query.

8.2. Working with CLI

- Overview of CLI options

  ```
  cli_help
  ```

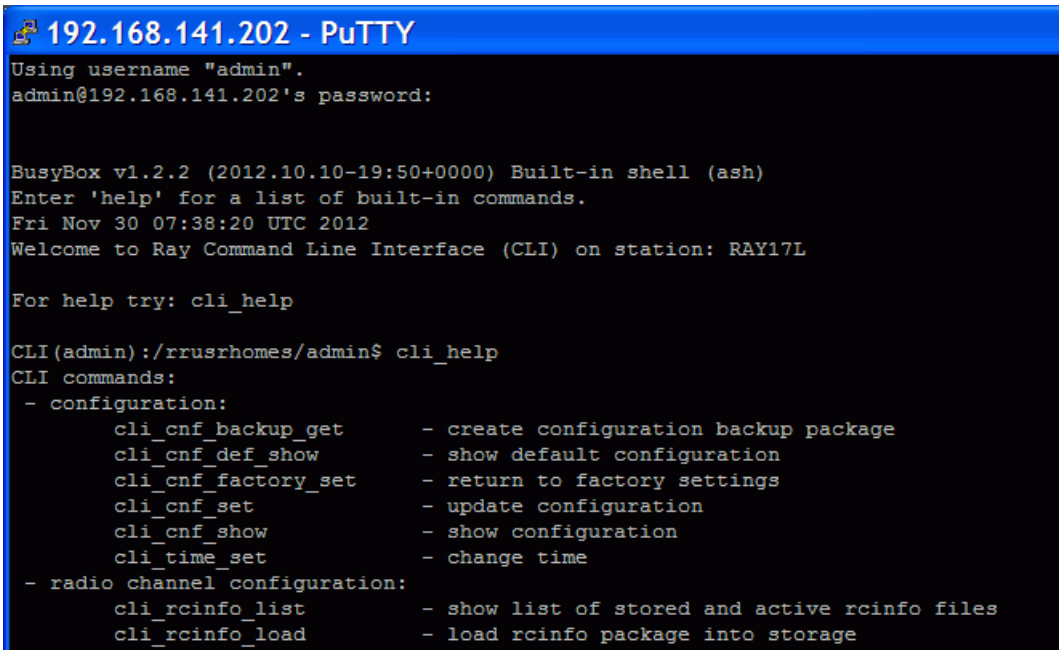


Fig. 8.1: CLI menu

- Parameters of CLI commands are listed in the help. For example:

`-h`	help listing
`-t`	target unit
`-t l`	local, default option
`-t b`	both, both units, command item for remote unit has PEER_ prefix
`-t p`	peer, opposite unit, when reading using the show command

- When inserting commands, using the tabulator can help
- An incorrect command is rejected (e.g. inserting forbidden frequency)
- A parameter that caused the loss of the connection is restored after 1 minute (Rollback)
- Reading parameters of local unit
  ```
  cli_cnf_show
  ```
- Reading radio parameters of peer unit
  ```
  cli_cnf_show -t p | grep RADIO
  ```
- Entering parameters (TX power of local unit)
  ```
  cli_cnf_set RADIO_TX_PWR=-3
  ```
  Items of command (RADIO_TX_PWR=) are taken from the list cli_cnf_show

- Entering more parameters in both units
  ```
  cli_cnf_set -t b RADIO_TX_CHAN=17128000 PEER_RADIO_RX_CHAN=17128000
  ```
- Put parameters containing spaces in quotation marks:
  ```
  cli_time_set -t b -T '2012-11-27 10:55:00'
  ```
  Set time in both units

8.2.1. SSH keys

- Generation using ssh-keygen
  ```
  [user@laptop ~]$ ssh-keygen -t dsa -f usr_ssh_key
  ```
  Uses working directory to save private `usr_ssh_key` and public part of the key `usr_ssh_key.pub`
- Copying the key into the RAy2 unit
  ```
  [user@laptop ~]$ scp usr_ssh_key.pub admin@192.168.141.202:/tmp
  ```
  The public part of the key is written to the folder `/tmp`
- Installation of key in RAy2 unit
  ```
  CLI(admin):/rrusrhomes/admin$ cli_user_authkey -c a -k /tmp/usr_ssh_key.pub
  ```
- Testing access to RAy2 unit using SSH key
  ```
  [user@laptop ~]$ ssh -i usr_ssh_key admin@192.168.141.202
  ```

8.2.2. Scripts

- Script example with access using key

```
[user@laptop ~]$ ssh -i usr_ssh_key admin@192.168.141.202
"source /etc/profile;cli_info_link;echo \$?;cli_cnf_show | grep TX_PWR;echo $?"
Warning: Permanently added '192.168.141.202' (DSA) to the list of known hosts.
cli_info_link: Link status: up
0
RADIO_TX_PWR=4
0
[user@laptop ~]$
```

- The script contains:

`source /etc/profile;`	environment settings
`cli_info_link;`	query for link status
`echo \$?;`	reading return value
`cli_cnf_show | grep TX_PWR;`	query for radio power
`echo \$?`	reading return value
`cli_info_link: Link status:up`	return value
`0`	OK command
`RADIO_TX_PWR=4`	power +4 dBm
`0`	OK command

8.3. Configuration with CLI

8.3.1. Configuration file

- Configuration backup
  `cli_cnf_backup_get`
  Saves the configuration of both units to file `cnf_backup.tgz` into the working directory.

- Configuration restore
  `cli_cnf_set -t b -b cnf_backup.tgz`
  Restores configuration of both units from file `cnf_backup.tgz`

- Default configuration list
  `cli_cnf_def_show`
  Warning, the command
  `cli_cnf_factory_set`
  is not a default setting - it uses factory settings, deleting all logs and saved data. It is very likely that the connection to peer unit will be interrupted!

8.3.2. Firmware upgrade

- Current version of fw
  `cli_info_station`

- Preparation of files
  fw package, for example `bm4-RACOM-0.1.12.0.cpio` copy using ssh or putty into folder `/tmp` in RAy17
  Command
  `cli_fw_clear_buffer`
  Clears the RAy2 buffer
  `cli_fw_buffer_status`
  Checks buffer status

- Saving into buffers
  `cli_fw_load_package -f /tmp/bm4-RACOM-0.1.12.0.cpio`
  A new fw package is loaded into the buffer (20 sec)
  `cli_fw_upload2peer`
  The fw package is also loaded into the peer unit (20 sec)

- Upgrade
  `cli_fw_upgrade -t b`
  Firmware in both units will be replaced with new version from the buffer. After 3 minutes, this message appears:
  `Firmware upgrade started. Estimated time to finish is 370 s.`
  Connection is terminated. After a few minutes, log in to RAy2 again

8.3.3. Remote unit authorization

The RAy2 unit in default configuration, establishes a connection with any remote unit and both units act as a communication pair. Should the higher protection from the unauthorized communication take-over be required, it is possible to use the so called Secured mode of remote unit authorization. This mode is based on locking the two specific units into one communication pair. Units with Secured mode

activated refuse to make a connection with any other communication unit. The units are locked using the unique authorization keys. The keys are exchanged between the units concerned. The authorization keys can be backed up to an external medium to be able to make a service unit exchange, if necessary. Should The *Link authorization quard* be disabled, the user data occurs even it the remote unit is not authorized.

The Secured mode set up process consists of a few steps:

- Unique authorization keys generation:
  `cli_link_key_gen -t b`
- Authorization keys exchange between the two communication units:
  `cli_link_key_swap`
- Authorization keys activation:
  `cli_link_key_apply -t b`
  Parameter `-t` determines whether we configure the whole link (`-t b`) or only one unit (`-t l`).
- Secured mode activation. Both sides of the link must have identically secured mode set On or Off:
  `cli_cnf_set -t b SVC_SECURE_PEER_MODE=on PEER_SVC_SECURE_PEER_MODE=on`
- Secured mode de-activation:
  `cli_cnf_set -t b SVC_SECURE_PEER_MODE=off PEER_SVC_SECURE_PEER_MODE=off`
- Backup of the keys to an external medium. The backup has to be performed to be able to make service exchange of the corrupted unit, if necessary. The new exchanged unit is not able to make an active connection with the other unit if it is not loaded with the proper authorization key.
  `cli_link_key_save -s s -f <file>`
  The key is backed up to a selected file in the internal unit file system. It can be transferred to an external medium using for example the scp client.
- Authorization key restoration from the external medium.
  The key has to be transferred to the unit internal file system first. The scp client can be used. The CLI commands can be applied subsequently:
  `cli_link_key_load -t b -f <file>`
  `cli_link_key_apply -t b`

9. Troubleshooting

- **Polarization incorrect**

  Install the unit with the correct *horizontal* or *vertical* polarization: The arrow mark (placed just next to the Status LED) indicates the unit RX polarization. When the arrow is perpendicular to the earth, the unit receives a signal in vertical polarization. When the arrow is parallel to the earth, the unit receives a signal in horizontal polarization. The connectors must point downward at an angle.

- **The link cannot be established**

  Start with the most “resilient” configuration. This configuration depends on the type of unit. We recommend using the narrowest available bandwidth (e.g. 3.5 MHz), the lowest modulation level (QPSK) and maximum available output power. TX and RX channels must be the same as the RX and TX channels in the remote unit. When the connection has been established and the antennas have been directed, proceed with operation parameters.

  Units operating in licensed bands (RAy2-10, RAy2-11) are mounted with the same RX polarization (the polarization indication arrows show the same polarization on both units).

  Units working in the bands equipped with RAy2-17 and RAy2-24 units must be mounted with opposite polarization; one with RX horizontal polarization (horizontal arrow) and the second with RX vertical polarization (vertical arrow).

- **Access to the Local unit is blocked**

  Access to the Local unit may be accidentally blocked, for instance by disabling HTTPS access. If you can access the Remote unit over HTTPS, type its address in your web browser's address field. The link will transfer the packet over the Local unit with blocked service access all the way to the Remote unit, which will give you access to the control menus of both units. Warning, the Remote unit will report as Local.

- **Distinguishing Local-Remote**

  A unit accessed via service access always reports as Local. If you connect through another (peer) unit and radio channel, a certain amount of caution is necessary. For example, do not reduce the transmission power so that the link interrupts accidentally. Errors of this type should be fixed by the rollback function within approx. 1 minute.

  Resolution can be done by comparing the length of ping on Local and Remote. Pinging the unit behind the radio channel is slower. The difference is more pronounced in the case of a long packet and the low speed of the radio channel.

- **Access security**

  For better protection against unauthorised access to configuration you should only allow as few kinds of access as possible. The most secure type is SSH with key – leave only SSH active with "only key" choice.

- **RSS**

  To configure the link and monitor its state, several menus display the RSS signal strength. Please keep in mind, that Ray2 is not a measuring instrument, hence the precision of the RSS reading is

limited. Though, in most situations the RSS reading accuracy is better than ± 2dB, the absolute RSS value should not be used for accurate comparisons e.g. between two links.

- **Problem with https certificate**

  See the Appendix G, *Https certificate*

- **Overexcited receiver**

  A natural property of each radio receiver is to compress the signal in one of the functional blocks, typically in a second receiving mixer. A downside of this property is the distortion of the input signal (decrease in the signal to noise ratio, i.e. the distortion measured as SNR).

  In extreme cases, this can lead to the disintegration of the radio link due to reduced signal to noise ratio (distortion). Extreme limits for guaranteed availability of the RAy2 connections are:

  - -30 dB for all channel bandwidths and fixed modulation 256QAM
  - -10 dB for all channel bandwidths and fixed modulation QPSK

10. Technical parameters

10.1. General parameters

10.1.1. Technical parameters overview

Tab. 10.1: Technical parameters

Type	RAy2-10	RAy2-11	RAy2-17	RAy2-24
Band [GHz], sub-bands A,B..	A: 10.30 – 10.59	A: 10.695 – 11.460	17.1 – 17.3	24.0 – 24.25
	B: 10.125 – 10.675	B: 10.935 – 11.695		
ODU inits	Unit L and U		One universal unit	
Duplex spacing [MHz]	any combination L and U units	490, 530	optional min 60	optional min 60
Channel spacing CS [MHz]	1.75, 3.5, 7, 14, 20, 28, 56	1.75, 3.5, 7, 14, 28, 30, 40, 56	3.5, 7, 14, 28, 40, 50, 56	3.5, 7, 14, 28, 40, 50, 56
Channel freq.	detail	detail	detail	detail
User speed [Mbps]	2.5 – 360	2.5 – 360	4.9 – 360	4.9 – 360
	detail	detail	detail	detail
Latency [µs]	81 (64B/359Mbps), 234 (1518B/359Mbps)			
Sensitivity, BER 10^{-6} [dBm]	-100 (2.5 Mbps) -67 (340 Mbps)	-99 (2.5 Mbps) -67 (340 Mbps)	-96 (4.9 Mbps) -66 (340 Mbps)	-96 (4.9 Mbps) -65 (340 Mbps)
	detail	detail	detail	detail
Output Power [dBm]	-10 – +13 (QPSK) -10 – +8 (256QAM)	-15 – +24 (QPSK) -15 – +19 (256QAM)	-25 – +5	-30 – +10
ATPC	yes	yes	yes	yes
Consumption [W]	21	21 – 29	21	23
Weight [kg]	2.8	2.8	2.5	2.5
Radio param.	EN 302 217-2-2 V2.1.1		EN 300 440-2 V1.4.1	

ver. 2.11

Modulation	fixed QPSK, 16, 32, 64, 128, 256 QAM or ACM
Forward Error Correc.	LDPC
User interface RJ45	1 Gb Eth. (10/100/1000) (IEEE 802.3ac 1000BASE-T) , MTU 10240 B, recommended cable S/FTP CAT7
User interface SFP	1000Base-SX / 1000Base-LX, MTU 10240 B, user exchangable SFP, power consumption max. 1.25 W
Service	USB-A
Power	PoE, 40 - 60 VDC , IEEE 802.3at up to 100m, up to 25 W
	DC, 20 - 60 V, floating
Operating temperature range	-30 – +55°C (EN 300 019-1-4, class 4.1.)
Mechanical design	FOD (Full Outdoor)
Security	configuration via https, ssh
Dimensions	244 × 244 × 157 mm
EMC	EN 301 489-1 V1.9.2 EN 301 489-4 V2.1.1
Electrical safety	EN 60 950-1:2006

ver. 1.3

10.1.2. Link speed

Nominal link speed

RAy2 - xx	**User data rate [Mbps]**										
Modula-tion	**1.75 MHz**	**3.5 MHz**	**7 MHz**	**14 MHz**	**20 MHz**	**28 / 30 MHz**		**40 MHz**	**50 MHz**	**56 MHz**	**56 MHz TO**
	ACCP	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACAP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**
QPSK	2.5	4.9	8.5	19.9	22.8	36.8	38.3	50.1	66.3	72.9	85.8
16-QAM	4.9	9.6	17.2	38.8	50.2	80.9	84.1	110.0	145.6	160.2	169.9
32-QAM	6.3	12.1	22.1	49.1	63.5	102.4	106.4	139.2	184.2	202.7	206.2
64-QAM	7.4	14.3	29.7	62.3	80.5	129.8	135.0	176.5	233.6	256.9	268.1
128-QAM	8.9	17.2	34.7	73.6	96.4	155.5	161.7	211.4	276.1	303.7	309.0
256-QAM		19.7	40.7	81.2	110.4	170.7	185.2	232.1	320.6	337.7	358.9

ver. 2.7

Link speed according to RFC 2544

RAy2 - xx	**Link speed [Mbps] for frames 64 - 1518 B**								minimum maximum values
Modulation / CS	**1.75 MHz**	**3.5 MHz**	**7 MHz**	**14 MHz**	**28 / 30 MHz**		**40 MHz**	**56 MHz**	**56 MHz TO**
	ACCP	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACAP**	**ACCP**	**ACCP**	**ACCP**
QPSK	2.1 2.3	4.2 4.6	7.5 8.3	17.6 19.6	32.6 36.5	33.8 37.9	44.3 49.6	64.7 72.3	76.1 85.2
16-QAM	4.3 4.8	8.4 9.3	15.1 17.0	34.3 38.5	71.7 80.2	74.6 83.4	97.5 109.2	142.1 159.0	150.7 168.6
32-QAM	5.4 6.0	10.6 11.9	19.6 21.8	43.4 48.6	90.7 101.5	94.3 105.6	123.4 138.2	179.9 201.3	182.9 204.8
64-QAM	6.5 7.2	12.6 14.1	26.1 29.3	55.2 61.7	115.1 128.8	119.7 133.9	156.6 175.3	228.0 255.1	238.1 266.4
128-QAM	7.8 8.7	15.1 17.0	30.7 34.3	65.2 73.0	138.0 154.5	143.5 160.5	187.7 209.9	269.7 301.6	274.5 307.1
256-QAM		17.4 19.4	36.1 40.3	71.9 80.5	151.5 169.5	164.4 184.0	206.1 230.7	300.2 335.8	318.8 356.5

ver. 1.1

ACM switching according to SNR state

RAy2 - xx	**SNR degrade / improve [dB]**									
Modulation / CS	**1.75 MHz**	**3.5 MHz**	**7 MHz**	**14 MHz**	**20 MHz**	**28 MHz**	**40 MHz**	**50 MHz**	**56 MHz**	**56 MHz TO**
	ACCP	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**	**ACCP**
QPSK	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0	- 19.0
16-QAM	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0	17.0 23.0
32-QAM	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.0 26.0	20.5 26.0
64-QAM	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	23.0 28.5	24.5 28.5
128-QAM	25.0 -	25.0 31.5	25.0 30.5	25.0 30.5	25.0 30.5	25.0 30.5	25.0 30.5	25.0 30.5	25.0 30.5	27.0 31.0
256-QAM	- -	28.5 -	28.0 -	28.0 -	28.0 -	28.0 -	28.0 -	28.0 -	28.0 -	29.0 -

ver. 1.2

10.2. Nominal frequency tables description

RAy11 – xA , **RAy11 – x**B [1]	TX channel nominal frequencies Band 10.7 – 11.7 GHz, [3] duplex frequency 490 MHz [4]
Bandwidth: **56 MHz (CS 80)** [2]	CEPT 12-06 Annex C [5]

A sub-band [6] (Freq.table: rcinfo11_A_490, rcinfo11_A_490_n) [7]			**B** sub-band (Freq.table: rcinfo11_B_490, rcinfo11_B_490_n)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1 [8]	10755 [9]	11245 [10]	7	10995	11485
2	10795	11285	8	11035	11525
3	10835	11325	9	11075	11565
4	10875	11365	10	11115	11605
5	10915	11405	11	11155	11645

ver. 1.0 [11]

1) The respective RAy unit name. The letter “x” stands for “L” or “U” (Lower or Upper band unit). Example: “RAy11-xA” means both “RAy11-LA” and “RAy11-UA” units. See overview table for details.
NOTE: The optional last figure in the unit name (e.g. RAy11-LA-2) denotes number of Ethernet ports and it is not relevant for the Nominal frequency tables.

2) The respective channel set (nominal frequencies) name in the Ray unit configuration interface (see Configuration, item “Bandwith [MHz]”. In addition to the bandwith definition, the name may contain additional text which defines the respective alternative of channel plan. Examples:
- “Bandwith: 40 MHz (ITU)” means that the nominal frequencies in the table follow the recommendation ITU-R F.387 rec.1.2. for 40 MHz bandwith, see also the note 5) below.
- “Bandwith: 40 MHz (ACMA)” means that the table describes the 40 MHz channel plan defined by ITU-R F.387 rec. 1.1. (b), applied e.g. in Australia.

3) The complete frequency range (approx.)

4) Duplex spacing – the frequency difference between the Upper and Lower channels in a duplex pair.
Optional: The minimum and the maximal duplex spacing used in the table of frequencies.

5) The name of standard or recommendation defining the respective channel plan.

6) Name of the sub-band defined by channels in the table.

7) Name of the “Frequency table” containing the channel set described (see Configuration, item "Frequency tables").

8) The channel number according to RAy unit configuration interface (see Configuration, item “TX channel [GHz]”).

9) The nominal TX frequency of the Lower-band channel

10) The nominal TX frequency of the Upper-band channel.

11) Table version.

10.3. RAy2-10 parameters

10.3.1. Upper/Lower Limits

RAy2-10-xA, **RAy2-10-xB**	**TX power**	
Modulation	**Min**	**Max**
	[dBm]	**[dBm]**
QPSK	-10	13
16-QAM	-10	11
32-QAM	-10	11
64-QAM	-10	10
128-QAM	-10	9
256-QAM	-10	8

ver. 1.2

RAy2-10-xA, **RAy2-10-xB**	**Duplex spacing**
Sub-band	**[MHz]**
A	All combinations of channels
B	All combinations of channels

ver. 2.5

RAy2-10-xA, **RAy2-10-xB**		**Sub-band Range**	
Sub-band		**Unit L**	**Unit U**
		[MHz]	**[MHz]**
A	min	10.300	10.470
	max	10.420	10.590
B	min	10.125	10.475
	max	10.325	11.675

ver. 1.1

10.3.2. Radio parameters

RAy2-10			Channel spacing 1.75 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	3.1	2.5	-100	9.5	17 / 23	12 / 19	-12 / 0	-14 / -4
16-QAM	6.3	5.0	-92	15.0	22 / 30	20 / 26.5	-11 / -3	-13 / -7
32-QAM	7.8	6.3	-88	19.0	24 / 30	22 / 26.5	-10 / -3	-12 / -7
64-QAM	9.4	7.4	-87	20.5	29 / 30	26 / 26.5	-9 / -3	-10 / -7
128-QAM	11.0	8.9	-84	23.5	30 / 33	29 / 29	-5 / -5	-9 / -9

ver. 2.4

RAy2-10			Channel spacing 3.5 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-96	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-89	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-86	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-85	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-83	23.5	30 / 30	26 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-80	26.0	33 / 40	31 / 36	-7 / 0	-6 / -4

ver. 2.4

RAy2-10			Channel spacing 7 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-94	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-87	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-84	18.5	24 / 33	22 / 29	-16 / -5	-18 / -9
64-QAM	36	29.7	-80	21.5	29 / 34	26 / 30	-14 / -3	-16 / -7
128-QAM	42	34.7	-78	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	39.7	-76	26.0	33 / 40	31 / 36	-10 / 0	-12 / -4

ver. 2.4

RAy2-10					Channel spacing 14 MHz; ACCP operation			
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-92	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-85	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-81	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-78	21.5	28 / 34	26 / 30	-14 / -3	-17 / -7
128-QAM	84	73.6	-75	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-73	28.0	33 / 40	31 / 36	-10 / 0	-12 / -4

ver. 2.4

RAy2-10					Channel spacing 20 MHz; ACCP operation			
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	31	22.8	-91	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	62	50.2	-84	15.0	20 / 30	18 / 26.5	-19 / -8	-21 / -12
32-QAM	77.5	63.5	-80	18.5	26 / 30	23 / 26.5	-17 / -8	-19 / -12
64-QAM	93	80.5	-77	21.5	28 / 30	26 / 26.5	-14 / -8	-17 / -12
128QAM	108.5	96.4	-73	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	124	110.4	-71	28.0	33 / 40	31 / 36	-10 / 0	-12 / -4

ver. 2.4

RAy2-10					Channel spacing 28 / 30 MHz; ACCP operation			
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-90	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-82	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-78	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-75	21.5	28 / 34	26 / 30	-12 / -3	-15 / -7
128QAM	175	155.5	-71	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-69	26.5	33 / 40	31 / 36	-6 / 0	-9 / -4

ver. 2.4

RAy2-10					Channel spacing 28 / 30 MHz; ACAP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	52	38.3	-88.5	7.5	12 / 23	10 / 19	-15 / 0	-17 / -4
16-QAM	104	84.1	-81.5	15.0	20 / 30	18 / 26.5	-12 / -3	-14 / -7
32-QAM	130	106.4	-77.5	18.5	24 / 33	22 / 29	-10 / -5	-13 / -9
64-QAM	156	135.0	-74.5	21.5	28 / 34	26 / 30	-6 / 4	-9 / 1
128QAM	182	161.7	-70.5	25.0	30 / 40	28 / 36	-3 / 10	-6 / 7
256-QAM	208	185.2	-67.5	26.5	33 / 43	31 / 39	0 / 10	-3 / 6

ver. 2.4

RAy2-10					Channel spacing 56 MHz; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	72.9	-86	7.5	12 / 23	10 / 19	-26 / 0	-28 / -4
16-QAM	198	160.2	-79	15.0	19 / 30	17 / 26.5	-19 / -3	-21 / -7
32-QAM	247.5	202.7	-75	18.5	24 / 33	22 / 29	-15 / -5	-17 / -9
64-QAM	297	256.9	-72	21.5	27 / 34	25 / 30	-14 / -3	-16 / -7
128QAM	346.5	303.7	-68	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	396	337.7	-66	26.5	33 / 40	30 / 36	-8 / 0	-10 / -4

ver. 2.4

RAy2-10					Channel spacing 56 MHz TO; ACCP operation			
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	85.8	-84	10.0	13 / 23	11 / 19	-24 / 0	-26 / -4
16-QAM	198	169.9	-77	16.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	247.5	206.2	-73	19.0	25 / 33	23 / 29	-14 / -5	-15 / -9
64-QAM	297	268.1	-69	22.5	29 / 34	26 / 30	-9 / -3	-11 / -7
128QAM	346.5	309.0	-66	25.5	32 / 35	29 / 32	-8 / -5	-10 / -8
256-QAM	396	358.9	-63	27.5	35 / 43	32 / 39	-7 / 0	-8 / -4

ver. 2.4

10.3.3. Nominal frequencies, band 10.30 – 10.59 GHz

RAy2-10 – x**A**	TX channel nominal frequencies	
	Band 10.30 – 10.59 GHz	default duplex 168 MHz
Bandwidth: **1.75 MHz**	Channel arrangements based on 7 MHz	duplex range 57.75 – 285.25 MHz
A sub-band	(Freq.table: rcinfo10_A_default:6)	

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10301.875				
2	10303.625				
3	10305.375				
4	10307.125				
5	10308.875	10476.875	37	10364.875	10532.875
6	10310.625	10478.625	38	10366.625	10534.625
7	10312.375	10480.375	39	10368.375	10536.375
8	10314.125	10482.125	40	10370.125	10538.125
9	10315.875	10483.875	41	10371.875	10539.875
10	10317.625	10485.625	42	10373.625	10541.625
11	10319.375	10487.375	43	10375.375	10543.375
12	10321.125	10489.125	44	10377.125	10545.125
13	10322.875	10490.875	45	10378.875	10546.875
14	10324.625	10492.625	46	10380.625	10548.625
15	10326.375	10494.375	47	10382.375	10550.375
16	10328.125	10496.125	48	10384.125	10552.125
17	10329.875	10497.875	49	10385.875	10553.875
18	10331.625	10499.625	50	10387.625	10555.625
19	10333.375	10501.375	51	10389.375	10557.375
20	10335.125	10503.125	52	10391.125	10559.125
21	10336.875	10504.875	53	10392.875	10560.875
22	10338.625	10506.625	54	10394.625	10562.625
23	10340.375	10508.375	55	10396.375	10564.375
24	10342.125	10510.125	56	10398.125	10566.125
25	10343.875	10511.875	57	10399.875	10567.875
26	10345.625	10513.625	58	10401.625	10569.625
27	10347.375	10515.375	59	10403.375	10571.375
28	10349.125	10517.125	60	10405.125	10573.125
29	10350.875	10518.875	61	10406.875	10574.875
30	10352.625	10520.625	62	10408.625	10576.625
31	10354.375	10522.375	63	10410.375	10578.375
32	10356.125	10524.125	64	10412.125	10580.125
33	10357.875	10525.875	65	10413.875	10581.875
34	10359.625	10527.625	66	10415.625	10583.625
35	10361.375	10529.375	67	10417.375	10585.375
36	10363.125	10531.125	68	10419.125	10587.125

ver. 2.0

RAy2-10 – x**A**	TX channel nominal frequencies	
	Band 10.30 – 10.59 GHz	default duplex 168 MHz
Bandwidth: **3.5 MHz**	Channel arrangements based on 7 MHz	duplex range 59.5 – 283.5 MHz
A sub-band	(Freq.table: rcinfo10_A_default:6)	

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10302.75				
2	10306.25				
3	10309.75	10477.75	19	10365.75	10533.75
4	10313.25	10481.25	20	10369.25	10537.25
5	10316.75	10484.75	21	10372.75	10540.75
6	10320.25	10488.25	22	10376.25	10544.25
7	10323.75	10491.75	23	10379.75	10547.75
8	10327.25	10495.25	24	10383.25	10551.25
9	10330.75	10498.75	25	10386.75	10554.75
10	10334.25	10502.25	26	10390.25	10558.25
11	10337.75	10505.75	27	10393.75	10561.75
12	10341.25	10509.25	28	10397.25	10565.25
13	10344.75	10512.75	29	10400.75	10568.75
14	10348.25	10516.25	30	10404.25	10572.25
15	10351.75	10519.75	31	10407.75	10575.75
16	10355.25	10523.25	32	10411.25	10579.25
17	10358.75	10526.75	33	10414.75	10582.75
18	10362.25	10530.25	34	10418.25	10586.25

ver. 2.0

RAy2-10 – x**A**	TX channel nominal frequencies	
	Band 10.30 – 10.59 GHz	default duplex 168 MHz
Bandwidth: **7 MHz**	VO-R/14/12.2012-17	duplex range 63 – 280 MHz
A sub-band	(Freq.table: rcinfo10_A_default:6)	

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10304.5				
2	10308.0				
3	10311.5	10479.5	11	10367.5	10535.5
4	10318.5	10486.5	12	10374.5	10542.5
5	10325.5	10493.5	13	10381.5	10549.5
6	10332.5	10500.5	14	10388.5	10556.5
7	10339.5	10507.5	15	10395.5	10563.5
8	10346.5	10514.5	16	10402.5	10570.5
9	10353.5	10521.5	17	10409.5	10577.5
10	10360.5	10528.5	18	10416.5	10584.5

ver. 2.0

RAy2-10 – x**A**	TX channel nominal frequencies	default duplex 168 MHz
Bandwidth: **14 MHz**	Band 10.30 – 10.59 GHz VO-R/14/12.2012-17	duplex range 70 – 273 MHz
A sub-band	(Freq.table: rcinfo10_A_default:6)	

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10308				
2	10315	10483	6	10371	10539
3	10329	10497	7	10385	10553
4	10343	10511	8	10399	10567
5	10357	10525	9	10413	10581

ver. 2.0

RAy2-10 – x**A**	TX channel nominal frequencies	default duplex 168 MHz
Bandwidth: **28 MHz**	Band 10.30 – 10.59 GHz VO-R/14/12.2012-17	duplex range 84 – 252 MHz
A sub-band	(Freq.table: rcinfo10_A_default:6)	

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10322	10490	3	10378	10546
2	10350	10518	4	10406	10574

ver. 2.0

RAy2-10 – x**A**	TX channel nominal frequencies	default duplex 168 MHz
Bandwidth: **56 MHz**	Band 10.30 – 10.59 GHz Channel arrangements based on 7 MHz	duplex range 112 – 224 MHz
A sub-band	(Freq.table: rcinfo10_A_default:6)	

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10336	10504	2	10392	10560

ver. 2.0

10.3.4. Nominal frequencies, band 10.15 – 10.65 GHz

RAy2-10 - x**B**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz, duplex spacing 350 MHz

Bandwidth: **1.75 MHz**

Based on 3.5 MHz channels

B sub-band

(Freq.table: rcinfo10_B_default:5)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10151.375	10501.375	43	10224.875	10574.875
2	10153.125	10503.125	44	10226.625	10576.625
3	10154.875	10504.875	45	10228.375	10578.375
4	10156.625	10506.625	46	10230.125	10580.125
5	10158.375	10508.375	47	10231.875	10581.875
6	10160.125	10510.125	48	10233.625	10583.625
7	10161.875	10511.875	49	10235.375	10585.375
8	10163.625	10513.625	50	10237.125	10587.125
9	10165.375	10515.375	51	10238.875	10588.875
10	10167.125	10517.125	52	10240.625	10590.625
11	10168.875	10518.875	53	10242.375	10592.375
12	10170.625	10520.625	54	10244.125	10594.125
13	10172.375	10522.375	55	10245.875	10595.875
14	10174.125	10524.125	56	10247.625	10597.625
15	10175.875	10525.875	57	10249.375	10599.375
16	10177.625	10527.625	58	10251.125	10601.125
17	10179.375	10529.375	59	10252.875	10602.875
18	10181.125	10531.125	60	10254.625	10604.625
19	10182.875	10532.875	61	10256.375	10606.375
20	10184.625	10534.625	62	10258.125	10608.125
21	10186.375	10536.375	63	10259.875	10609.875
22	10188.125	10538.125	64	10261.625	10611.625
23	10189.875	10539.875	65	10263.375	10613.375
24	10191.625	10541.625	66	10265.125	10615.125
25	10193.375	10543.375	67	10266.875	10616.875
26	10195.125	10545.125	68	10268.625	10618.625
27	10196.875	10546.875	69	10270.375	10620.375
28	10198.625	10548.625	70	10272.125	10622.125
29	10200.375	10550.375	71	10273.875	10623.875
30	10202.125	10552.125	72	10275.625	10625.625
31	10203.875	10553.875	73	10277.375	10627.375
32	10205.625	10555.625	74	10279.125	10629.125
33	10207.375	10557.375	75	10280.875	10630.875
34	10209.125	10559.125	76	10282.625	10632.625
35	10210.875	10560.875	77	10284.375	10634.375
36	10212.625	10562.625	78	10286.125	10636.125
37	10214.375	10564.375	79	10287.875	10637.875
38	10216.125	10566.125	80	10289.625	10639.625
39	10217.875	10567.875	81	10291.375	10641.375
40	10219.625	10569.625	82	10293.125	10643.125
41	10221.375	10571.375	83	10294.875	10644.875
42	10223.125	10573.125	84	10296.625	10646.625

ver. 2.0

RAy2-10 - x**B**	TX channel nominal frequencies Band 10.15 – 10.65 GHz, duplex spacing 350 MHz
Bandwidth: **3.5 MHz**	CEPT/ERC/REC 12-05 E
B sub-band	(Freq.table: rcinfo10_B_default:5)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10152.25	10502.25	22	10225.75	10575.75
2	10155.75	10505.75	23	10229.25	10579.25
3	10159.25	10509.25	24	10232.75	10582.75
4	10162.75	10512.75	25	10236.25	10586.25
5	10166.25	10516.25	26	10239.75	10589.75
6	10169.75	10519.75	27	10243.25	10593.25
7	10173.25	10523.25	28	10246.75	10596.75
8	10176.75	10526.75	29	10250.25	10600.25
9	10180.25	10530.25	30	10253.75	10603.75
10	10183.75	10533.75	31	10257.25	10607.25
11	10187.25	10537.25	32	10260.75	10610.75
12	10190.75	10540.75	33	10264.25	10614.25
13	10194.25	10544.25	34	10267.75	10617.75
14	10197.75	10547.75	35	10271.25	10621.25
15	10201.25	10551.25	36	10274.75	10624.75
16	10204.75	10554.75	37	10278.25	10628.25
17	10208.25	10558.25	38	10281.75	10631.75
18	10211.75	10561.75	39	10285.25	10635.25
19	10215.25	10565.25	40	10288.75	10638.75
20	10218.75	10568.75	41	10292.25	10642.25
21	10222.25	10572.25	42	10295.75	10645.75

ver. 2.0

RAy2-10 - x**B**	TX channel nominal frequencies Band 10.15 – 10.65 GHz, duplex spacing 350 MHz
Bandwidth: **7 MHz**	CEPT/ERC/REC 12-05 E
B sub-band	(Freq.table: rcinfo10_B_default:5)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10157.5	10507.5	11	10227.5	10577.5
2	10164.5	10514.5	12	10234.5	10584.5
3	10171.5	10521.5	13	10241.5	10591.5
4	10178.5	10528.5	14	10248.5	10598.5
5	10185.5	10535.5	15	10255.5	10605.5
6	10192.5	10542.5	16	10262.5	10612.5
7	10199.5	10549.5	17	10269.5	10619.5
8	10206.5	10556.5	18	10276.5	10626.5
9	10213.5	10563.5	19	10283.5	10633.5
10	10220.5	10570.5	20	10290.5	10640.5

ver. 2.0

RAy2-10 - x**B**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz, duplex spacing 350 MHz

Bandwidth: **14 MHz**

CEPT/ERC/REC 12-05 E + 7 MHz based channels

B sub-band

(Freq.table: rcinfo10_B_default:5)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	**10161**	**10511**	**6**	**10231**	**10581**
1c	10168	10518	6c	10238	10588
2	**10175**	**10525**	**7**	**10245**	**10595**
2c	10182	10532	7c	10252	10602
3	**10189**	**10539**	**8**	**10259**	**10609**
3c	10196	10546	8c	10266	10616
4	**10203**	**10553**	**9**	**10273**	**10623**
4c	10210	10560	9c	10280	10630
5	**10217**	**10567**	**10**	**10287**	**10637**
5c	10224	10574			

ver. 2.0

RAy2-10 - x**B**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz, duplex spacing 350 MHz

Bandwidth: **20 MHz**

B sub-band

(Freq.table: rcinfo10_B_default:5)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10175	10525	4	10235	10585
2	10195	10545	5	10255	10605
3	10215	10565	6	10275	10625

ver. 1.0

RAy2-10 - x**B**

TX channel nominal frequencies
Band 10.15 – 10.65 GHz, duplex spacing 350 MHz

Bandwidth: **28 MHz**

CEPT/ERC/REC 12-05 E

B sub-band

(Freq.table: rcinfo10_B_default:5)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10168	10518	4	10252	10602
2	10196	10546	5	10280	10630
3	10224	10574			

ver. 2.0

RAy2-10 - x**B**			TX channel nominal frequencies Band 10.15 – 10.65 GHz, duplex spacing 350 MHz		
Bandwidth: **56 MHz**			CEPT/ERC/REC 12-05 E		
B sub-band			(Freq.table: rcinfo10_B_default:5)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10182	10532	3	10238	10588
2	10210	10560	4	10266	10616

ver. 2.0

10.4. RAy2-11 A,B parameters

10.4.1. Upper/Lower Limits

RAy2-11-xA, **RAy2-11-x**B	**TX power**	
Modulation	**Min**	**Max**
	[dBm]	**[dBm]**
QPSK	-15	24
16-QAM	-15	22
32-QAM	-15	22
64-QAM	-15	21
128-QAM	-15	20
256-QAM	-15	19

ver. 2.2

RAy2-11-xA, **RAy2-11-x**B	**Duplex spacing**
Sub-band	**[MHz]**
A	490, 530
B	490, 530

ver. 2.5

RAy2-11-xA, **RAy2-11-x**B		**Sub-band Range**	
Sub-band		**Unit L**	**Unit U**
		[MHz]	**[MHz]**
A	min	10.695	11.185
	max	10.970	11.460
B	min	10.935	11.425
	max	11.195	11.695

ver. 1.0

10.4.2. Radio parameters

RAy2-11-xA, RAy2-11-xB					Channel spacing 1.75 MHz; ACCP operation			
Modulation	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	3.1	2.5	-99	9.5	15 / 23	12 / 19	-12 / 0	-14 / -4
16-QAM	6.3	5.0	-93	15.0	22 / 30	20 / 26.5	-11 / -3	-13 / -7
32-QAM	7.8	6.3	-89	19.0	24 / 30	22 / 26.5	-10 / -3	-12 / -7
64-QAM	9.4	7.4	-88	20.5	29 / 30	26 / 26.5	-9 / -3	-10 / -7
128-QAM	11.0	8.9	-84	23.5	30 / 30	28 / 26.5	-8 / -3	-7 / -7

ver. 2.3

RAy2-11-xA, RAy2-11-xB					Channel spacing 3.5 MHz; ACCP operation			
Modulation	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-97	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-90	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-87	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-84	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-81	23.5	30 / 30	28 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-79	26.0	33 / 30	31 / 26.5	-5 / -3	-7 / -7

ver. 2.2

RAy2-11-xA, RAy2-11-xB					Channel spacing 7 MHz; ACCP operation			
Modulation	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-95	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-88	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-85	18.5	24 / 30	22 / 26.5	-16 / -3	-18 / -7
64-QAM	36	29.7	-81	21.5	29 / 34	26 / 30	-14 / -3	-16 / -7
128-QAM	42	34.7	-79	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	40.7	-76	26.0	33 / 40	31 / 36	-10 / 0	-12 / -4

ver. 2.4

RAy2-11-xA, RAy2-11-xB			Channel spacing 14 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-93	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-86	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-82	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-79	21.5	28 / 34	26 / 30	-14 / -3	-17 / -7
128-QAM	84	73.6	-75	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-73	28.0	33 / 40	31 / 36	-10 / 0	-12 / -4

ver. 2.2

RAy2-11-xA, RAy2-11-xB			Channel spacing 28 / 30 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-91	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-83	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-79	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-76	21.5	28 / 34	26 / 30	-12 / -3	-15 / -7
128QAM	175	155.5	-72	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-70	26.5	33 / 40	31 / 36	-6 / 0	-9 / -4

ver. 2.1

RAy2-11-xA, RAy2-11-xB			Channel spacing 28 / 30 MHz; ACAP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	52	38.3	-89.5	7.5	12 / 23	10 / 19	-15 / 0	-17 / -4
16-QAM	104	84.1	-82.5	15.0	20 / 30	18 / 26.5	-12 / -3	-14 / -7
32-QAM	130	106.4	-78.5	18.5	24 / 33	22 / 29	-10 / -5	-13 / -9
64-QAM	156	135.0	-75.5	21.5	28 / 34	26 / 30	-6 / 4	-9 / 1
128QAM	182	161.7	-71.5	25.0	30 / 40	28 / 36	-3 / 10	-6 / 7
256-QAM	208	185.2	-68.5	26.5	33 / 43	31 / 39	0 / 10	-3 / 6

ver. 2.2

RAy2-11-xA, RAy2-11-xB			Channel spacing 40 MHz; ACCP operation					
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK.	68	50.1	-88	7.5	12 / 33	10 / 29	-22 / -4	-24 / -8
16-QAM	136	110.0	-81	15.0	19 / 33	17 / 29	-18 / -4	-21 / -8
32-QAM	170	139.2	-77	18.5	24 / 33	21 / 29	-16 / -4	-19 / -8
64-QAM	204	176.5	-74	21.5	27 / 33	25 / 29	-14 / -4	-16 / -8
128QAM	238	211.4	-70	25.0	30 / 37	28 / 33	-10 / -4	-12 / -8
256-QAM	272	232.1	-68	26.5	33 / 40	30 / 36	-8 / 0	-10 / -4

ver. 2.1

RAy2-11-xA, RAy2-11-xB			Channel spacing 56 MHz; ACCP operation					
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	72.9	-87	7.5	12 / 23	10 / 19	-26 / 0	-28 / -4
16-QAM	198	160.2	-80	15.0	19 / 30	17 / 26.5	-19 / -3	-21 / -7
32-QAM	247.5	202.7	-76	18.5	24 / 33	22 / 29	-15 / -5	-17 / -9
64-QAM	297	256.9	-73	21.5	27 / 34	25 / 30	-14 / 4	-16 / 1
128QAM	346.5	303.7	-69	25.0	30 / 37	28 / 33	-10 / 3	-12 / -1
256-QAM	396	337.7	-67	26.5	33 / 40	30 / 36	-8 / 10	-10 / 7

ver. 2.1

RAy2-11-xA, RAy2-11-xB			Channel spacing 56 MHz TO; ACCP operation					
Modula-tion	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	85.8	-85	10.0	13 / 23	11 / 19	-24 / 0	-26 / -4
16-QAM	198	169.9	-78	16.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	247.5	206.2	-74	19.0	25 / 33	23 / 29	-14 / -5	-15 / -9
64-QAM	297	268.1	-70	22.5	29 / 34	26 / 30	-9 / 4	-11 / 1
128QAM	346.5	309.0	-67	25.5	32 / 35	29 / 32	-8 / -5	-10 / -8
256-QAM	396	358.9	-64	27.5	35 / 43	32 / 39	-7 / 0	-8 / -4

ver. 2.2

10.4.3. Nominal frequencies, duplex 490 MHz

RAy2-11 - xA, RAy2-11 - xB

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz
Bandwidth: **1.75 MHz**
Channel arrangements based on 28 MHz channels

A sub-band (Freq. table: rcinfo11_A_490_default:13)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10709.875	11199.875	76	10841.125	11331.125
2	10711.625	11201.625	77	10842.875	11332.875
3	10713.375	11203.375	78	10844.625	11334.625
4	10715.125	11205.125	79	10846.375	11336.375
5	10716.875	11206.875	80	10848.125	11338.125
6	10718.625	11208.625	81	10849.875	11339.875
7	10720.375	11210.375	82	10851.625	11341.625
8	10722.125	11212.125	83	10853.375	11343.375
9	10723.875	11213.875	84	10855.125	11345.125
10	10725.625	11215.625	85	10856.875	11346.875
11	10727.375	11217.375	86	10858.625	11348.625
12	10729.125	11219.125	87	10860.375	11350.375
13	10730.875	11220.875	88	10862.125	11352.125
14	10732.625	11222.625	89	10863.875	11353.875
15	10734.375	11224.375	90	10865.625	11355.625
16	10736.125	11226.125	91	10867.375	11357.375
17	10737.875	11227.875	92	10869.125	11359.125
18	10739.625	11229.625	93	10870.875	11360.875
19	10741.375	11231.375	94	10872.625	11362.625
20	10743.125	11233.125	95	10874.375	11364.375
21	10744.875	11234.875	96	10876.125	11366.125
22	10746.625	11236.625	97	10877.875	11367.875
23	10748.375	11238.375	98	10879.625	11369.625
24	10750.125	11240.125	99	10881.375	11371.375
25	10751.875	11241.875	100	10883.125	11373.125
26	10753.625	11243.625	101	10884.875	11374.875
27	10755.375	11245.375	102	10886.625	11376.625
28	10757.125	11247.125	103	10888.375	11378.375
29	10758.875	11248.875	104	10890.125	11380.125
30	10760.625	11250.625	105	10891.875	11381.875
31	10762.375	11252.375	106	10893.625	11383.625
32	10764.125	11254.125	107	10895.375	11385.375
33	10765.875	11255.875	108	10897.125	11387.125
34	10767.625	11257.625	109	10898.875	11388.875
35	10769.375	11259.375	110	10900.625	11390.625
36	10771.125	11261.125	111	10902.375	11392.375
37	10772.875	11262.875	112	10904.125	11394.125
38	10774.625	11264.625	113	10905.875	11395.875
39	10776.375	11266.375	114	10907.625	11397.625
40	10778.125	11268.125	115	10909.375	11399.375
41	10779.875	11269.875	116	10911.125	11401.125
42	10781.625	11271.625	117	10912.875	11402.875
43	10783.375	11273.375	118	10914.625	11404.625
44	10785.125	11275.125	119	10916.375	11406.375
45	10786.875	11276.875	120	10918.125	11408.125
46	10788.625	11278.625	121	10919.875	11409.875
47	10790.375	11280.375	122	10921.625	11411.625
48	10792.125	11282.125	123	10923.375	11413.375
49	10793.875	11283.875	124	10925.125	11415.125
50	10795.625	11285.625	125	10926.875	11416.875
51	10797.375	11287.375	126	10928.625	11418.625
52	10799.125	11289.125	127	10930.375	11420.375
53	10800.875	11290.875	128	10932.125	11422.125
54	10802.625	11292.625	129	10933.875	11423.875
55	10804.375	11294.375	130	10935.625	11425.625
56	10806.125	11296.125	131	10937.375	11427.375
57	10807.875	11297.875	132	10939.125	11429.125
58	10809.625	11299.625	133	10940.875	11430.875
59	10811.375	11301.375	134	10942.625	11432.625
60	10813.125	11303.125	135	10944.375	11434.375
61	10814.875	11304.875	136	10946.125	11436.125
62	10816.625	11306.625	137	10947.875	11437.875
63	10818.375	11308.375	138	10949.625	11439.625
64	10820.125	11310.125	139	10951.375	11441.375
65	10821.875	11311.875	140	10953.125	11443.125
66	10823.625	11313.625	141	10954.875	11444.875
67	10825.375	11315.375	142	10956.625	11446.625
68	10827.125	11317.125	143	10958.375	11448.375
69	10828.875	11318.875	144	10960.125	11450.125
70	10830.625	11320.625	145	10961.875	11451.875
71	10832.375	11322.375	146	10963.625	11453.625
72	10834.125	11324.125	147	10965.375	11455.375
73	10835.875	11325.875	148	10967.125	11457.125
74	10837.625	11327.625	149	10968.875	11458.875
75	10839.375	11329.375			

B sub-band (Freq. table: rcinfo11_B_490_default:13)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
131	10937.375	11427.375	206	11068.625	11558.625
132	10939.125	11429.125	207	11070.375	11560.375
133	10940.875	11430.875	208	11072.125	11562.125
134	10942.625	11432.625	209	11073.875	11563.875
135	10944.375	11434.375	210	11075.625	11565.625
136	10946.125	11436.125	211	11077.375	11567.375
137	10947.875	11437.875	212	11079.125	11569.125
138	10949.625	11439.625	213	11080.875	11570.875
139	10951.375	11441.375	214	11082.625	11572.625
140	10953.125	11443.125	215	11084.375	11574.375
141	10954.875	11444.875	216	11086.125	11576.125
142	10956.625	11446.625	217	11087.875	11577.875
143	10958.375	11448.375	218	11089.625	11579.625
144	10960.125	11450.125	219	11091.375	11581.375
145	10961.875	11451.875	220	11093.125	11583.125
146	10963.625	11453.625	221	11094.875	11584.875
147	10965.375	11455.375	222	11096.625	11586.625
148	10967.125	11457.125	223	11098.375	11588.375
149	10968.875	11458.875	224	11100.125	11590.125
150	10970.625	11460.625	225	11101.875	11591.875
151	10972.375	11462.375	226	11103.625	11593.625
152	10974.125	11464.125	227	11105.375	11595.375
153	10975.875	11465.875	228	11107.125	11597.125
154	10977.625	11467.625	229	11108.875	11598.875
155	10979.375	11469.375	230	11110.625	11600.625
156	10981.125	11471.125	231	11112.375	11602.375
157	10982.875	11472.875	232	11114.125	11604.125
158	10984.625	11474.625	233	11115.875	11605.875
159	10986.375	11476.375	234	11117.625	11607.625
160	10988.125	11478.125	235	11119.375	11609.375
161	10989.875	11479.875	236	11121.125	11611.125
162	10991.625	11481.625	237	11122.875	11612.875
163	10993.375	11483.375	238	11124.625	11614.625
164	10995.125	11485.125	239	11126.375	11616.375
165	10996.875	11486.875	240	11128.125	11618.125
166	10998.625	11488.625	241	11129.875	11619.875
167	11000.375	11490.375	242	11131.625	11621.625
168	11002.125	11492.125	243	11133.375	11623.375
169	11003.875	11493.875	244	11135.125	11625.125
170	11005.625	11495.625	245	11136.875	11626.875
171	11007.375	11497.375	246	11138.625	11628.625
172	11009.125	11499.125	247	11140.375	11630.375
173	11010.875	11500.875	248	11142.125	11632.125
174	11012.625	11502.625	249	11143.875	11633.875
175	11014.375	11504.375	250	11145.625	11635.625
176	11016.125	11506.125	251	11147.375	11637.375
177	11017.875	11507.875	252	11149.125	11639.125
178	11019.625	11509.625	253	11150.875	11640.875
179	11021.375	11511.375	254	11152.625	11642.625
180	11023.125	11513.125	255	11154.375	11644.375
181	11024.875	11514.875	256	11156.125	11646.125
182	11026.625	11516.625	257	11157.875	11647.875
183	11028.375	11518.375	258	11159.625	11649.625
184	11030.125	11520.125	259	11161.375	11651.375
185	11031.875	11521.875	260	11163.125	11653.125
186	11033.625	11523.625	261	11164.875	11654.875
187	11035.375	11525.375	262	11166.625	11656.625
188	11037.125	11527.125	263	11168.375	11658.375
189	11038.875	11528.875	264	11170.125	11660.125
190	11040.625	11530.625	265	11171.875	11661.875
191	11042.375	11532.375	266	11173.625	11663.625
192	11044.125	11534.125	267	11175.375	11665.375
193	11045.875	11535.875	268	11177.125	11667.125
194	11047.625	11537.625	269	11178.875	11668.875
195	11049.375	11539.375	270	11180.625	11670.625
196	11051.125	11541.125	271	11182.375	11672.375
197	11052.875	11542.875	272	11184.125	11674.125
198	11054.625	11544.625			
199	11056.375	11546.375			
200	11058.125	11548.125			
201	11059.875	11549.875			
202	11061.625	11551.625			
203	11063.375	11553.375			
204	11065.125	11555.125			
205	11066.875	11556.875			

ver. 2.2

RAy2-11 - xA, RAy2-11 - xB

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **3.5 MHz**
Channel arrangements based on 28 MHz channels

A sub-band	(Freq. table: rcinfo11_A_490_default:13)					**B** sub-band	(Freq. table: rcinfo11_B_490_default:13)				
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10710.75	11200.75	38	10840.25	11330.25	66	10938.25	11428.25	103	11067.75	11557.75
2	10714.25	11204.25	39	10843.75	11333.75	67	10941.75	11431.75	104	11071.25	11561.25
3	10717.75	11207.75	40	10847.25	11337.25	68	10945.25	11435.25	105	11074.75	11564.75
4	10721.25	11211.25	41	10850.75	11340.75	69	10948.75	11438.75	106	11078.25	11568.25
5	10724.75	11214.75	42	10854.25	11344.25	70	10952.25	11442.25	107	11081.75	11571.75
6	10728.25	11218.25	43	10857.75	11347.75	71	10955.75	11445.75	108	11085.25	11575.25
7	10731.75	11221.75	44	10861.25	11351.25	72	10959.25	11449.25	109	11088.75	11578.75
8	10735.25	11225.25	45	10864.75	11354.75	73	10962.75	11452.75	110	11092.25	11582.25
9	10738.75	11228.75	46	10868.25	11358.25	74	10966.25	11456.25	111	11095.75	11585.75
10	10742.25	11232.25	47	10871.75	11361.75	75	10969.75	11459.75	112	11099.25	11589.25
11	10745.75	11235.75	48	10875.25	11365.25	76	10973.25	11463.25	113	11102.75	11592.75
12	10749.25	11239.25	49	10878.75	11368.75	77	10976.75	11466.75	114	11106.25	11596.25
13	10752.75	11242.75	50	10882.25	11372.25	78	10980.25	11470.25	115	11109.75	11599.75
14	10756.25	11246.25	51	10885.75	11375.75	79	10983.75	11473.75	116	11113.25	11603.25
15	10759.75	11249.75	52	10889.25	11379.25	80	10987.25	11477.25	117	11116.75	11606.75
16	10763.25	11253.25	53	10892.75	11382.75	81	10990.75	11480.75	118	11120.25	11610.25
17	10766.75	11256.75	54	10896.25	11386.25	82	10994.25	11484.25	119	11123.75	11613.75
18	10770.25	11260.25	55	10899.75	11389.75	83	10997.75	11487.75	120	11127.25	11617.25
19	10773.75	11263.75	56	10903.25	11393.25	84	11001.25	11491.25	121	11130.75	11620.75
20	10777.25	11267.25	57	10906.75	11396.75	85	11004.75	11494.75	122	11134.25	11624.25
21	10780.75	11270.75	58	10910.25	11400.25	86	11008.25	11498.25	123	11137.75	11627.75
22	10784.25	11274.25	59	10913.75	11403.75	87	11011.75	11501.75	124	11141.25	11631.25
23	10787.75	11277.75	60	10917.25	11407.25	88	11015.25	11505.25	125	11144.75	11634.75
24	10791.25	11281.25	61	10920.75	11410.75	89	11018.75	11508.75	126	11148.25	11638.25
25	10794.75	11284.75	62	10924.25	11414.25	90	11022.25	11512.25	127	11151.75	11641.75
26	10798.25	11288.25	63	10927.75	11417.75	91	11025.75	11515.75	128	11155.25	11645.25
27	10801.75	11291.75	64	10931.25	11421.25	92	11029.25	11519.25	129	11158.75	11648.75
28	10805.25	11295.25	65	10934.75	11424.75	93	11032.75	11522.75	130	11162.25	11652.25
29	10808.75	11298.75	66	10938.25	11428.25	94	11036.25	11526.25	131	11165.75	11655.75
30	10812.25	11302.25	67	10941.75	11431.75	95	11039.75	11529.75	132	11169.25	11659.25
31	10815.75	11305.75	68	10945.25	11435.25	96	11043.25	11533.25	133	11172.75	11662.75
32	10819.25	11309.25	69	10948.75	11438.75	97	11046.75	11536.75	134	11176.25	11666.25
33	10822.75	11312.75	70	10952.25	11442.25	98	11050.25	11540.25	135	11179.75	11669.75
34	10826.25	11316.25	71	10955.75	11445.75	99	11053.75	11543.75	136	11183.25	11673.25
35	10829.75	11319.75	72	10959.25	11449.25	100	11057.25	11547.25			
36	10833.25	11323.25	73	10962.75	11452.75	101	11060.75	11550.75			
37	10836.75	11326.75	74	10966.25	11456.25	102	11064.25	11554.25			

ver. 2.2

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **7 MHz**

Channel arrangements based on 28 MHz channels

A sub-band (Freq. table: rcinfo11_A_490_default:14)			**B** sub-band (Freq. table: rcinfo11_B_490_default:14)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10712.5	11202.5	34	10943.5	11433.5
2	10719.5	11209.5	35	10950.5	11440.5
3	10726.5	11216.5	36	10957.5	11447.5
4	10733.5	11223.5	37	10964.5	11454.5
5	10740.5	11230.5	38	10971.5	11461.5
6	10747.5	11237.5	39	10978.5	11468.5
7	10754.5	11244.5	40	10985.5	11475.5
8	10761.5	11251.5	41	10992.5	11482.5
9	10768.5	11258.5	42	10999.5	11489.5
10	10775.5	11265.5	43	11006.5	11496.5
11	10782.5	11272.5	44	11013.5	11503.5
12	10789.5	11279.5	45	11020.5	11510.5
13	10796.5	11286.5	46	11027.5	11517.5
14	10803.5	11293.5	47	11034.5	11524.5
15	10810.5	11300.5	48	11041.5	11531.5
16	10817.5	11307.5	49	11048.5	11538.5
17	10824.5	11314.5	50	11055.5	11545.5
18	10831.5	11321.5	51	11062.5	11552.5
19	10838.5	11328.5	52	11069.5	11559.5
20	10845.5	11335.5	53	11076.5	11566.5
21	10852.5	11342.5	54	11083.5	11573.5
22	10859.5	11349.5	55	11090.5	11580.5
23	10866.5	11356.5	56	11097.5	11587.5
24	10873.5	11363.5	57	11104.5	11594.5
25	10880.5	11370.5	58	11111.5	11601.5
26	10887.5	11377.5	59	11118.5	11608.5
27	10894.5	11384.5	60	11125.5	11615.5
28	10901.5	11391.5	61	11132.5	11622.5
29	10908.5	11398.5	62	11139.5	11629.5
30	10915.5	11405.5	63	11146.5	11636.5
31	10922.5	11412.5	64	11153.5	11643.5
32	10929.5	11419.5	65	11160.5	11650.5
33	10936.5	11426.5	66	11167.5	11657.5
34	10943.5	11433.5	67	11174.5	11664.5
35	10950.5	11440.5	68	11181.5	11671.5
36	10957.5	11447.5			
37	10964.5	11454.5			

ver. 2.3

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **14 MHz**

Channel arrangements based on 28 MHz channels

A sub-band	(Freq. table: rcinfo11_A_490_default:13)		**B** sub-band	(Freq. table: rcinfo11_B_490_default:13)	
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10716	11206	18	10954	11444
2	10730	11220	19	10968	11458
3	10744	11234	20	10982	11472
4	10758	11248	21	10996	11486
5	10772	11262	22	11010	11500
6	10786	11276	23	11024	11514
7	10800	11290	24	11038	11528
8	10814	11304	25	11052	11542
9	10828	11318	26	11066	11556
10	10842	11332	27	11080	11570
11	10856	11346	28	11094	11584
12	10870	11360	29	11108	11598
13	10884	11374	30	11122	11612
14	10898	11388	31	11136	11626
15	10912	11402	32	11150	11640
16	10926	11416	33	11164	11654
17	10940	11430	34	11178	11668
18	10954	11444			

ver. 2.2

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **28 MHz**

CEPT Rec. 12-06, Annex B.2

A sub-band	(Freq. table: rcinfo11_A_490_default:13)		**B** sub-band	(Freq. table: rcinfo11_B_490_default:13)	
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10723	11213	10	10975	11465
2	10751	11241	11	11003	11493
3	10779	11269	12	11031	11521
4	10807	11297	13	11059	11549
5	10835	11325	14	11087	11577
6	10863	11353	15	11115	11605
7	10891	11381	16	11143	11633
8	10919	11409	17	11171	11661
9	10947	11437			

ver. 2.2

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **30 MHz** IC

A sub-band (Freq. table: rcinfo11_A_490_default:13)			**B** sub-band (Freq. table: rcinfo11_B_490_default:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10725	11215	9	10965	11455
2	10755	11245	10	10995	11485
3	10785	11275	11	11025	11515
4	10815	11305	12	11055	11545
5	10845	11335	13	11085	11575
6	10875	11365	14	11115	11605
7	10905	11395	15	11145	11635
8	10935	11425	16	11175	11665

ver. 1.1

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **40 MHz (CEPT)** CEPT 12-06 Annex B.1, ITU-R F.387 rec.1.2

A sub-band (Freq. table: rcinfo11_A_490_default:13)			**B** sub-band (Freq. table: rcinfo11_B_490_default:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10735	11225	7	10975	11465
2	10775	11265	8	11015	11505
3	10815	11305	9	11055	11545
4	10855	11345	10	11095	11585
5	10895	11385	11	11135	11625
6	10935	11425	12	11175	11665

ver. 1.3

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **40 MHz (ACMA)** ACMA

A sub-band (Freq. table: rcinfo11_A_490_default:13)			**B** sub-band (Freq. table: rcinfo11_B_490_default:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10715	11205	7	10955	11445
2	10755	11245	8	10995	11485
3	10795	11285	9	11035	11525
4	10835	11325	10	11075	11565
5	10875	11365	11	11115	11605
6	10915	11405	12	11155	11645

ver. 1.2

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **56 MHz** CEPT 12-06, Annex C

A sub-band	(Freq. table: rcinfo11_A_490_default:13)		**B** sub-band	(Freq. table: rcinfo11_B_490_default:13)	
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10737	11227	10	10989	11479
2	10765	11255	11	11017	11507
3	10793	11283	12	11045	11535
4	10821	11311	13	11073	11563
5	10849	11339	14	11101	11591
6	10877	11367	15	11129	11619
7	10905	11395	16	11157	11647
8	10933	11423			

ver. 2.2

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 490 MHz

Bandwidth: **56 (CS 80) MHz** CEPT 12-06, Annex C

A sub-band	(Freq. table: rcinfo11_A_490_default:13)		**B** sub-band	(Freq. table: rcinfo11_B_490_default:13)	
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10755	11245	7	10995	11485
2	10795	11285	8	11035	11525
3	10835	11325	9	11075	11565
4	10875	11365	10	11115	11605
5	10915	11405	11	11155	11645

ver. 1.1

10.4.4. Nominal frequencies, duplex 530 MHz

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **1.75 MHz**

Channel arrangements based on 28 MHz channels

A sub-band (Freq. table: rcinfo11_A_530:13)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10709.875	11239.875	64	10820.125	11350.125
2	10711.625	11241.625	65	10821.875	11351.875
3	10713.375	11243.375	66	10823.625	11353.625
4	10715.125	11245.125	67	10825.375	11355.375
5	10716.875	11246.875	68	10827.125	11357.125
6	10718.625	11248.625	69	10828.875	11358.875
7	10720.375	11250.375	70	10830.625	11360.625
8	10722.125	11252.125	71	10832.375	11362.375
9	10723.875	11253.875	72	10834.125	11364.125
10	10725.625	11255.625	73	10835.875	11365.875
11	10727.375	11257.375	74	10837.625	11367.625
12	10729.125	11259.125	75	10839.375	11369.375
13	10730.875	11260.875	76	10841.125	11371.125
14	10732.625	11262.625	77	10842.875	11372.875
15	10734.375	11264.375	78	10844.625	11374.625
16	10736.125	11266.125	79	10846.375	11376.375
17	10737.875	11267.875	80	10848.125	11378.125
18	10739.625	11269.625	81	10849.875	11379.875
19	10741.375	11271.375	82	10851.625	11381.625
20	10743.125	11273.125	83	10853.375	11383.375
21	10744.875	11274.875	84	10855.125	11385.125
22	10746.625	11276.625	85	10856.875	11386.875
23	10748.375	11278.375	86	10858.625	11388.625
24	10750.125	11280.125	87	10860.375	11390.375
25	10751.875	11281.875	88	10862.125	11392.125
26	10753.625	11283.625	89	10863.875	11393.875
27	10755.375	11285.375	90	10865.625	11395.625
28	10757.125	11287.125	91	10867.375	11397.375
29	10758.875	11288.875	92	10869.125	11399.125
30	10760.625	11290.625	93	10870.875	11400.875
31	10762.375	11292.375	94	10872.625	11402.625
32	10764.125	11294.125	95	10874.375	11404.375
33	10765.875	11295.875	96	10876.125	11406.125
34	10767.625	11297.625	97	10877.875	11407.875
35	10769.375	11299.375	98	10879.625	11409.625
36	10771.125	11301.125	99	10881.375	11411.375
37	10772.875	11302.875	100	10883.125	11413.125
38	10774.625	11304.625	101	10884.875	11414.875
39	10776.375	11306.375	102	10886.625	11416.625
40	10778.125	11308.125	103	10888.375	11418.375
41	10779.875	11309.875	104	10890.125	11420.125
42	10781.625	11311.625	105	10891.875	11421.875
43	10783.375	11313.375	106	10893.625	11423.625
44	10785.125	11315.125	107	10895.375	11425.375
45	10786.875	11316.875	108	10897.125	11427.125
46	10788.625	11318.625	109	10898.875	11428.875
47	10790.375	11320.375	110	10900.625	11430.625
48	10792.125	11322.125	111	10902.375	11432.375
49	10793.875	11323.875	112	10904.125	11434.125
50	10795.625	11325.625	113	10905.875	11435.875
51	10797.375	11327.375	114	10907.625	11437.625
52	10799.125	11329.125	115	10909.375	11439.375
53	10800.875	11330.875	116	10911.125	11441.125
54	10802.625	11332.625	117	10912.875	11442.875
55	10804.375	11334.375	118	10914.625	11444.625
56	10806.125	11336.125	119	10916.375	11446.375
57	10807.875	11337.875	120	10918.125	11448.125
58	10809.625	11339.625	121	10919.875	11449.875
59	10811.375	11341.375	122	10921.625	11451.625
60	10813.125	11343.125	123	10923.375	11453.375
61	10814.875	11344.875	124	10925.125	11455.125
62	10816.625	11346.625	125	10926.875	11456.875
63	10818.375	11348.375	126	10928.625	11458.625

B sub-band (Freq. table: rcinfo11_B_530:13)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
131	10937.375	11467.375	196	11051.125	11581.125
132	10939.125	11469.125	197	11052.875	11582.875
133	10940.875	11470.875	198	11054.625	11584.625
134	10942.625	11472.625	199	11056.375	11586.375
135	10944.375	11474.375	200	11058.125	11588.125
136	10946.125	11476.125	201	11059.875	11589.875
137	10947.875	11477.875	202	11061.625	11591.625
138	10949.625	11479.625	203	11063.375	11593.375
139	10951.375	11481.375	204	11065.125	11595.125
140	10953.125	11483.125	205	11066.875	11596.875
141	10954.875	11484.875	206	11068.625	11598.625
142	10956.625	11486.625	207	11070.375	11600.375
143	10958.375	11488.375	208	11072.125	11602.125
144	10960.125	11490.125	209	11073.875	11603.875
145	10961.875	11491.875	210	11075.625	11605.625
146	10963.625	11493.625	211	11077.375	11607.375
147	10965.375	11495.375	212	11079.125	11609.125
148	10967.125	11497.125	213	11080.875	11610.875
149	10968.875	11498.875	214	11082.625	11612.625
150	10970.625	11500.625	215	11084.375	11614.375
151	10972.375	11502.375	216	11086.125	11616.125
152	10974.125	11504.125	217	11087.875	11617.875
153	10975.875	11505.875	218	11089.625	11619.625
154	10977.625	11507.625	219	11091.375	11621.375
155	10979.375	11509.375	220	11093.125	11623.125
156	10981.125	11511.125	221	11094.875	11624.875
157	10982.875	11512.875	222	11096.625	11626.625
158	10984.625	11514.625	223	11098.375	11628.375
159	10986.375	11516.375	224	11100.125	11630.125
160	10988.125	11518.125	225	11101.875	11631.875
161	10989.875	11519.875	226	11103.625	11633.625
162	10991.625	11521.625	227	11105.375	11635.375
163	10993.375	11523.375	228	11107.125	11637.125
164	10995.125	11525.125	229	11108.875	11638.875
165	10996.875	11526.875	230	11110.625	11640.625
166	10998.625	11528.625	231	11112.375	11642.375
167	11000.375	11530.375	232	11114.125	11644.125
168	11002.125	11532.125	233	11115.875	11645.875
169	11003.875	11533.875	234	11117.625	11647.625
170	11005.625	11535.625	235	11119.375	11649.375
171	11007.375	11537.375	236	11121.125	11651.125
172	11009.125	11539.125	237	11122.875	11652.875
173	11010.875	11540.875	238	11124.625	11654.625
174	11012.625	11542.625	239	11126.375	11656.375
175	11014.375	11544.375	240	11128.125	11658.125
176	11016.125	11546.125	241	11129.875	11659.875
177	11017.875	11547.875	242	11131.625	11661.625
178	11019.625	11549.625	243	11133.375	11663.375
179	11021.375	11551.375	244	11135.125	11665.125
180	11023.125	11553.125	245	11136.875	11666.875
181	11024.875	11554.875	246	11138.625	11668.625
182	11026.625	11556.625	247	11140.375	11670.375
183	11028.375	11558.375	248	11142.125	11672.125
184	11030.125	11560.125	249	11143.875	11673.875
185	11031.875	11561.875	250	11145.625	11675.625
186	11033.625	11563.625	251	11147.375	11677.375
187	11035.375	11565.375	252	11149.125	11679.125
188	11037.125	11567.125	253	11150.875	11680.875
189	11038.875	11568.875	254	11152.625	11682.625
190	11040.625	11570.625	255	11154.375	11684.375
191	11042.375	11572.375	256	11156.125	11686.125
192	11044.125	11574.125	257	11157.875	11687.875
193	11045.875	11575.875	258	11159.625	11689.625
194	11047.625	11577.625	259	11161.375	11691.375
195	11049.375	11579.375	260	11163.125	11693.125

ver. 2.3

RAy2-11 - x**A**, RAy2-11 - x**B**

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **3.5 MHz**

Channel arrangements based on 28 MHz channels

A sub-band (Freq. table: rcinfo11_A_530:13)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10710.75	11240.75	33	10822.75	11352.75
2	10714.25	11244.25	34	10826.25	11356.25
3	10717.75	11247.75	35	10829.75	11359.75
4	10721.25	11251.25	36	10833.25	11363.25
5	10724.75	11254.75	37	10836.75	11366.75
6	10728.25	11258.25	38	10840.25	11370.25
7	10731.75	11261.75	39	10843.75	11373.75
8	10735.25	11265.25	40	10847.25	11377.25
9	10738.75	11268.75	41	10850.75	11380.75
10	10742.25	11272.25	42	10854.25	11384.25
11	10745.75	11275.75	43	10857.75	11387.75
12	10749.25	11279.25	44	10861.25	11391.25
13	10752.75	11282.75	45	10864.75	11394.75
14	10756.25	11286.25	46	10868.25	11398.25
15	10759.75	11289.75	47	10871.75	11401.75
16	10763.25	11293.25	48	10875.25	11405.25
17	10766.75	11296.75	49	10878.75	11408.75
18	10770.25	11300.25	50	10882.25	11412.25
19	10773.75	11303.75	51	10885.75	11415.75
20	10777.25	11307.25	52	10889.25	11419.25
21	10780.75	11310.75	53	10892.75	11422.75
22	10784.25	11314.25	54	10896.25	11426.25
23	10787.75	11317.75	55	10899.75	11429.75
24	10791.25	11321.25	56	10903.25	11433.25
25	10794.75	11324.75	57	10906.75	11436.75
26	10798.25	11328.25	58	10910.25	11440.25
27	10801.75	11331.75	59	10913.75	11443.75
28	10805.25	11335.25	60	10917.25	11447.25
29	10808.75	11338.75	61	10920.75	11450.75
30	10812.25	11342.25	62	10924.25	11454.25
31	10815.75	11345.75	63	10927.75	11457.75
32	10819.25	11349.25			

B sub-band (Freq. table: rcinfo11_B_530:13)

Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
66	10938.25	11468.25	99	11053.75	11583.75
67	10941.75	11471.75	100	11057.25	11587.25
68	10945.25	11475.25	101	11060.75	11590.75
69	10948.75	11478.75	102	11064.25	11594.25
70	10952.25	11482.25	103	11067.75	11597.75
71	10955.75	11485.75	104	11071.25	11601.25
72	10959.25	11489.25	105	11074.75	11604.75
73	10962.75	11492.75	106	11078.25	11608.25
74	10966.25	11496.25	107	11081.75	11611.75
75	10969.75	11499.75	108	11085.25	11615.25
76	10973.25	11503.25	109	11088.75	11618.75
77	10976.75	11506.75	110	11092.25	11622.25
78	10980.25	11510.25	111	11095.75	11625.75
79	10983.75	11513.75	112	11099.25	11629.25
80	10987.25	11517.25	113	11102.75	11632.75
81	10990.75	11520.75	114	11106.25	11636.25
82	10994.25	11524.25	115	11109.75	11639.75
83	10997.75	11527.75	116	11113.25	11643.25
84	11001.25	11531.25	117	11116.75	11646.75
85	11004.75	11534.75	118	11120.25	11650.25
86	11008.25	11538.25	119	11123.75	11653.75
87	11011.75	11541.75	120	11127.25	11657.25
88	11015.25	11545.25	121	11130.75	11660.75
89	11018.75	11548.75	122	11134.25	11664.25
90	11022.25	11552.25	123	11137.75	11667.75
91	11025.75	11555.75	124	11141.25	11671.25
92	11029.25	11559.25	125	11144.75	11674.75
93	11032.75	11562.75	126	11148.25	11678.25
94	11036.25	11566.25	127	11151.75	11681.75
95	11039.75	11569.75	128	11155.25	11685.25
96	11043.25	11573.25	129	11158.75	11688.75
97	11046.75	11576.75	130	11162.25	11692.25
98	11050.25	11580.25			
99	11053.75	11583.75			

ver. 2.3

RAy2-11 - xA**, RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **7 MHz**

ITU-R F.387 , Annex 5

A sub-band (Freq. table: rcinfo11_A_530:13)			**B** sub-band (Freq. table: rcinfo11_B_530:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10712.5	11242.5	34	10943.5	11473.5
2	10719.5	11249.5	35	10950.5	11480.5
3	10726.5	11256.5	36	10957.5	11487.5
4	10733.5	11263.5	37	10964.5	11494.5
5	10740.5	11270.5	38	10971.5	11501.5
6	10747.5	11277.5	39	10978.5	11508.5
7	10754.5	11284.5	40	10985.5	11515.5
8	10761.5	11291.5	41	10992.5	11522.5
9	10768.5	11298.5	42	10999.5	11529.5
10	10775.5	11305.5	43	11006.5	11536.5
11	10782.5	11312.5	44	11013.5	11543.5
12	10789.5	11319.5	45	11020.5	11550.5
13	10796.5	11326.5	46	11027.5	11557.5
14	10803.5	11333.5	47	11034.5	11564.5
15	10810.5	11340.5	48	11041.5	11571.5
16	10817.5	11347.5	49	11048.5	11578.5
17	10824.5	11354.5	50	11055.5	11585.5
18	10831.5	11361.5	51	11062.5	11592.5
19	10838.5	11368.5	52	11069.5	11599.5
20	10845.5	11375.5	53	11076.5	11606.5
21	10852.5	11382.5	54	11083.5	11613.5
22	10859.5	11389.5	55	11090.5	11620.5
23	10866.5	11396.5	56	11097.5	11627.5
24	10873.5	11403.5	57	11104.5	11634.5
25	10880.5	11410.5	58	11111.5	11641.5
26	10887.5	11417.5	59	11118.5	11648.5
27	10894.5	11424.5	60	11125.5	11655.5
28	10901.5	11431.5	61	11132.5	11662.5
29	10908.5	11438.5	62	11139.5	11669.5
30	10915.5	11445.5	63	11146.5	11676.5
31	10922.5	11452.5	64	11153.5	11683.5
			65	11160.5	11690.5

ver. 2.2

RAy2-11 - x**A, RAy2-11 -** x**B**

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **14 MHz**

ITU-R F.387 , Annex 5

A sub-band (Freq. table: rcinfo11_A_530:13)			**B** sub-band (Freq. table: rcinfo11_B_530:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10716	11246	18	10954	11484
2	10730	11260	19	10968	11498
3	10744	11274	20	10982	11512
4	10758	11288	21	10996	11526
5	10772	11302	22	11010	11540
6	10786	11316	23	11024	11554
7	10800	11330	24	11038	11568
8	10814	11344	25	11052	11582
9	10828	11358	26	11066	11596
10	10842	11372	27	11080	11610
11	10856	11386	28	11094	11624
12	10870	11400	29	11108	11638
13	10884	11414	30	11122	11652
14	10898	11428	31	11136	11666
15	10912	11442	32	11150	11680

ver. 2.2

RAy2-11 - x**A, RAy2-11 -** x**B**

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **28 MHz**

ITU-R F.387 , Annex 5

A sub-band (Freq. table: rcinfo11_A_530:13)			**B** sub-band (Freq. table: rcinfo11_B_530:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10723	11253	10	10975	11505
2	10751	11281	11	11003	11533
3	10779	11309	12	11031	11561
4	10807	11337	13	11059	11589
5	10835	11365	14	11087	11617
6	10863	11393	15	11115	11645
7	10891	11421	16	11143	11673

ver. 2.2

RAy2-11 - xA, **RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **40 MHz (ITU)** ITU-R F.387 rec.1.1,

A sub-band (Freq. table: rcinfo11_A_530:13)			**B** sub-band (Freq. table: rcinfo11_B_530:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10715	11245	7	10955	11485
2	10755	11285	8	10995	11525
3	10795	11325	9	11035	11565
4	10835	11365	10	11075	11605
5	10875	11405	11	11115	11645

ver. 1.1

RAy2-11 - xA, **RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **40 MHz (CEPT)** CEPT 12-06 Annex A.1

A sub-band (Freq. table: rcinfo11_A_530:13)			**B** sub-band (Freq. table: rcinfo11_B_530:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10735	11265	7	10975	11505
2	10775	11305	8	11015	11545
3	10815	11345	9	11055	11585
4	10855	11385	10	11095	11625
5	10895	11425	11	11135	11665

ver. 1.2

RAy2-11 - xA, **RAy2-11 - x**B

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **56 MHz** CEPT 12-06, Annex C

A sub-band (Freq. table: rcinfo11_A_530:13)			**B** sub-band (Freq. table: rcinfo11_B_530:13)		
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10737	11267	10	10989	11519
2	10765	11295	11	11017	11547
3	10793	11323	12	11045	11575
4	10821	11351	13	11073	11603
5	10849	11379	14	11101	11631
6	10877	11407	15	11129	11659

ver. 2.2

RAy2-11 - x**A, RAy2-11 -** x**B**

TX channel nominal frequencies
Band 10.7 – 11.7 GHz, duplex spacing 530 MHz

Bandwidth: **56 (CS 80) MHz**

CEPT 12-06, Annex C

A sub-band	(Freq. table: rcinfo11_A_530:13)		**B** sub-band	(Freq. table: rcinfo11_B_530:13)	
Ch.No.	Lower [MHz]	Upper [MHz]	Ch.No.	Lower [MHz]	Upper [MHz]
1	10755	11285	7	10995	11525
2	10795	11325	8	11035	11565
3	10835	11365	9	11075	11605
4	10875	11405	10	11115	11645

ver. 1.1

10.5. RAy2-11 C,D parameters

Note

The RAy2-11-C,D units are not available yet

10.6. RAy2-17 parameters

10.6.1. Upper/Lower Limits

RAy2-17	TX power	
Modulation	Min	Max
	[dBm]	[dBm]
QPSK	-25	5
16-QAM	-25	5
32-QAM	-25	5
64-QAM	-25	5
128-QAM	-25	5
256-QAM	-25	5

ver. 2.0

Minimum (hw limit) and default duplex spacing.

RAy2-17	Optional duplex spacing	
Channel width	min	default
[MHz]	[MHz]	[MHz]
3.5	60	73.5
7	60	73.5
14	65	87.5
28	70	84
40	70	70
50	84	87.5
56	84	84

ver. 2.6

RAy2-17	Band Range	
	Unit L	Unit U
	[MHz]	[MHz]
min	17.100	17.100
max	17.300	17.300

ver. 1.0

10.6.2. Radio parameters

RAy2-17	Channel spacing 3.5 MHz; ACCP operation							
Modula-tion	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-97	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-90	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-87	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-84	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-83	23.5	30 / 30	28 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-81	26.0	33 / 30	31 / 26.5	-5 / -3	-7 / -7

ver. 2.1

RAy2-17	Channel spacing 7 MHz; ACCP operation							
Modula-tion	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-95	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-88	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-85	18.5	24 / 37	22 / 33	-16 / -2	-18 / -6
64-QAM	36	29.7	-81	21.5	29 / 37	26 / 33	-14 / -2	-16 / -6
128-QAM	42	34.7	-79	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	39.7	-77	26.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.1

RAy2-17	Channel spacing 14 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-92	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-85	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-81	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-78	21.5	28 / 37	26 / 33	-14 / -2	-17 / -6
128-QAM	84	73.6	-75	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-73	28.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 2.1

RAy2-17	Channel spacing 28 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-90	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-83	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-79	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-76	21.5	28 / 35	26 / 32	-12 / -5	-15 / -8
128QAM	175	155.5	-72	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-69	26.5	33 / 35	31 / 32	-6 / -5	-9 / -8

ver. 2.0

RAy2-17	Channel spacing 40 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	68	50.1	-88	7.5	12 / 33	10 / 29	-22 / -4	-24 / -8
16-QAM	136	110.0	-81	15.0	19 / 33	17 / 29	-18 / -4	-21 / -8
32-QAM	170	139.2	-77	18.5	24 / 33	21 / 29	-16 / -4	-19 / -8
64-QAM	204	176.5	-74	21.5	27 / 33	25 / 29	-14 / -4	-16 / -8
128QAM	238	211.4	-70	25.0	30 / 37	28 / 33	-10 / -4	-12 / -8
256-QAM	272	232.1	-68	26.5	33 / 37	30 / 33	-8 / -4	-10 / -8

ver. 2.0

RAy2-17			Channel spacing 50 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	90	66.3	-87.5	7.5	12 / 23	10 / 19	-24 / 0	-26 / -4
16-QAM	180	145.6	-80.5	15.0	19 / 30	17 / 26.5	-18 / -3	-21 / -7
32-QAM	225	184.2	-76.5	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	270	233.6	-73.5	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128QAM	315	276.1	-69.5	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	360	320.6	-66.5	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 1.0

RAy2-17			Channel spacing 56 MHz; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	72.9	-87	7.5	12 / 23	10 / 19	-24 / 0	-26 / -4
16-QAM	198	160.2	-80	15.0	19 / 30	17 / 26.5	-18 / -3	-21 / -7
32-QAM	247.5	202.7	-76	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	297	256.9	-73	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128QAM	346.5	303.7	-69	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	396	337.7	-66	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 2.0

RAy2-17			Channel spacing 56 MHz TO; ACCP operation					
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	85.8	-85	10.0	13 / 23	11 / 19	-24 / 0	-26 / -4
16-QAM	198	169.9	-78	16.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	247.5	206.2	-74	19.0	25 / 33	23 / 29	-14 / -5	-15 / -9
64-QAM	297	268.1	-70	22.5	29 / 35	26 / 32	-9 / -5	-11 / -8
128-QAM	346.5	309.0	-67	25.5	32 / 35	29 / 32	-8 / -5	-10 / -8
256-QAM	396	358.9	-64	27.5	35 / 35	32 / 32	-7 / -5	-8 / -8

ver. 2.1

10.6.3. Nominal frequencies

RAy2-17

TX channel nominal frequencies
Band 17.1 – 17.3 GHz, default duplex sp. **73.5** MHz
duplex spacing range 63 – 189 MHz

Bandwidth: **3.5 MHz**

(Freq.table: rcinfo17_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U19	17168.0	no more channels			
		U20	17171.5				
		U21	17175.0				
L1	17105.0	**U22**	17178.5				
L2	17108.5	**U23**	17182.0				
L3	17112.0	**U24**	17185.5				
L4	17115.5	**U25**	17189.0				
L5	17119.0	**U26**	17192.5				
L6	17122.5	**U27**	17196.0				
L7	17126.0	**U28**	17199.5				
L8	17129.5	**U29**	17203.0				
L9	17133.0	**U30**	17206.5				
L10	17136.5	**U31**	17210.0				
L11	17140.0	**U32**	17213.5				
L12	17143.5	**U33**	17217.0				
L13	17147.0	**U34**	17220.5				
L14	17150.5	**U35**	17224.0				
L15	17154.0	**U36**	17227.5				
L16	17157.5	**U37**	17231.0				
L17	17161.0	**U38**	17234.5				
L18	17164.5	**U39**	17238.0				
L19	17168.0	**U40**	17241.5				
L20	17171.5	**U41**	17245.0				
L21	17175.0	**U42**	17248.5				
L22	17178.5	**U43**	17252.0				
L23	17182.0	**U44**	17255.5				
L24	17185.5	**U45**	17259.0				
L25	17189.0	**U46**	17262.5				
L26	17192.5	**U47**	17266.0				
L27	17196.0	**U48**	17269.5				
L28	17199.5	**U49**	17273.0				
L29	17203.0	**U50**	17276.5				
L30	17206.5	**U51**	17280.0				
L31	17210.0	**U52**	17283.5				
L32	17213.5	**U53**	17287.0				
L33	17217.0	**U54**	17290.5				
L34	17220.5	**U55**	17294.0				
L35	17224.0						
L36	17227.5						
L37	17231.0						

ver. 2.1

RAy2-17 TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **73.5** MHz

Bandwidth: **7 MHz** duplex spacing range 63 – 189 MHz

(Freq.table: rcinfo17_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U19	17168.0			U20	17171.5
		U21	17175.0	L1	17105.0	U22	17178.5
L2	17108.5	**U23**	17182.0	L3	17112.0	U24	17185.5
L4	17115.5	**U25**	17189.0	L5	17119.0	U26	17192.5
L6	17122.5	**U27**	17196.0	L7	17126.0	U28	17199.5
L8	17129.5	**U29**	17203.0	L9	17133.0	U30	17206.5
L10	17136.5	**U31**	17210.0	L11	17140.0	U32	17213.5
L12	17143.5	**U33**	17217.0	L13	17147.0	U34	17220.5
L14	17150.5	**U35**	17224.0	L15	17154.0	U36	17227.5
L16	17157.5	**U37**	17231.0	L17	17161.0	U38	17234.5
L18	17164.5	**U39**	17238.0	L19	17168.0	U40	17241.5
L20	17171.5	**U41**	17245.0	L21	17175.0	U42	17248.5
L22	17178.5	**U43**	17252.0	L23	17182.0	U44	17255.5
L24	17185.5	**U45**	17259.0	L25	17189.0	U46	17262.5
L26	17192.5	**U47**	17266.0	L27	17196.0	U48	17269.5
L28	17199.5	**U49**	17273.0	L29	17203.0	U50	17276.5
L30	17206.5	**U51**	17280.0	L31	17210.0	U52	17283.5
L32	17213.5	**U53**	17287.0	L33	17217.0	U54	17290.5
L34	17220.5	**U55**	17294.0	L35	17224.0		
L36	17227.5			L37	17231.0		

ver. 2.1

RAy2-17

TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **87.5** MHz

Bandwidth: **14 MHz**

duplex spacing range 66.5 – 182 MHz

(Freq.table: rcinfo17_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U21	17175.0
		U22	17178.5				
						U23	17182.0
						U24	17185.5
						U25	17189.0
		U26	17192.5				
				L2	17108.5	U27	17196.0
				L3	17112.0	U28	17199.5
				L4	17115.5	U29	17203.0
L5	17119.0	**U30**	17206.5				
				L6	17122.5	U31	17210.0
				L7	17126.0	U32	17213.5
				L8	17129.5	U33	17217.0
L9	17133.0	**U34**	17220.5				
				L10	17136.5	U35	17224.0
				L11	17140.0	U36	17227.5
				L12	17143.5	U37	17231.0
L13	17147.0	**U38**	17234.5				
				L14	17150.5	U39	17238.0
				L15	17154.0	U40	17241.5
				L16	17157.5	U41	17245.0
L17	17161.0	**U42**	17248.5				
				L18	17164.5	U43	17252.0
				L19	17168.0	U44	17255.5
				L20	17171.5	U45	17259.0
L21	17175.0	**U46**	17262.5				
				L22	17178.5	U47	17266.0
				L23	17182.0	U48	17269.5
				L24	17185.5	U49	17273.0
L25	17189.0	**U50**	17276.5				
				L26	17192.5	U51	17280.0
				L27	17196.0	U52	17283.5
				L28	17199.5	U53	17287.0
L29	17203.0	**U54**	17290.5				
				L30	17206.5		
				L31	17210.0		
				L32	17213.5		
L33	17217.0						
				L34	17220.5		
				L35	17224.0		

ver. 2.1

RAy2-17

TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **84** MHz

Bandwidth: **28 MHz**

duplex spacing range 70 – 168 MHz

(Freq.table: rcinfo17_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U24	17185.5
						U25	17189.0
						U26	17192.5
						U27	17196.0
L4	17115.5	**U28**	17199.5				
				L5	17119.0	U29	17203.0
				L6	17122.5	U30	17206.5
				L7	17126.0	U31	17210.0
				L8	17129.5	U32	17213.5
				L9	17133.0	U33	17217.0
				L10	17136.5	U34	17220.5
				L11	17140.0	U35	17224.0
L12	17143.5	**U36**	17227.5				
				L13	17147.0	U37	17231.0
				L14	17150.5	U38	17234.5
				L15	17154.0	U39	17238.0
				L16	17157.5	U40	17241.5
				L17	17161.0	U41	17245.0
				L18	17164.5	U42	17248.5
				L19	17168.0	U43	17252.0
L20	17171.5	**U44**	17255.5				
				L21	17175.0	U45	17259.0
				L22	17178.5	U46	17262.5
				L23	17182.0	U47	17266.0
				L24	17185.5	U48	17269.5
				L25	17189.0	U49	17273.0
				L26	17192.5	U50	17276.5
				L27	17196.0	U51	17280.0
L28	17199.5	**U52**	17283.5				
				L29	17203.0		
				L30	17206.5		
				L31	17210.0		
				L32	17213.5		

ver. 2.1

RAy2-17

TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **70** MHz

Bandwidth: **40 MHz**

duplex spacing range 70 – 154 MHz

(Freq.table: rcinfo17_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L6	17122.5	**U26**	17192.5				
				L7	17126.0	U27	17196.0
				L8	17129.5	U28	17199.5
				L9	17133.0	U29	17203.0
				L10	17136.5	U30	17206.5
				L11	17140.0	U31	17210.0
				L12	17143.5	U32	17213.5
				L13	17147.0	U33	17217.0
				L14	17150.5	U34	17220.5
				L15	17154.0	U35	17224.0
				L16	17157.5	U36	17227.5
				L17	17161.0	U37	17231.0
L18	17164.5	**U38**	17234.5				
				L19	17168.0	U39	17238.0
				L20	17171.5	U40	17241.5
				L21	17175.0	U41	17245.0
				L22	17178.5	U42	17248.5
				L23	17182.0	U43	17252.0
				L24	17185.5	U44	17255.5
				L25	17189.0	U45	17259.0
				L26	17192.5	U46	17262.5
				L27	17196.0	U47	17266.0
				L28	17199.5	U48	17269.5
				L29	17203.0	U49	17273.0
L30	17206.5	**U50**	17276.5				

ver. 2.1

RAy2-17

TX channel nominal frequencies

Band 17.1 – 17.3 GHz, duplex spacing 87.5 MHz

Bandwidth: **50 MHz**

duplex spacing range 84 – 143.5 MHz

(Freq.table: rcinfo17_default:17)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U32	17213.5
				L8	17129.5	U33	17217.0
L9	17133.0	**U34**	17220.5				
				L10	17136.5	U35	17224.0
				L11	17140.0	U36	17227.5
				L12	17143.5	U37	17231.0
				L13	17147.0	U38	17234.5
				L14	17150.5	U39	17238.0
				L15	17154.0	U40	17241.5
				L16	17157.5	U41	17245.0
				L17	17161.0	U42	17248.5
				L18	17164.5	U43	17252.0
				L19	17168.0	U44	17255.5
				L20	17171.5	U45	17259.0
				L21	17175.0	U46	17262.5
				L22	17178.5	U47	17266.0
				L23	17182.0	U48	17269.5
L24	17185.5	**U49**	17273.0				
				L25	17189.0		

ver. 1.0

RAy2-17

TX channel nominal frequencies

Band 17.1 – 17.3 GHz, default duplex sp. **84** MHz

Bandwidth: **56 MHz**

duplex spacing range 84 – 140 MHz

(Freq.table: rcinfo17_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L8	17129.5	**U32**	17213.5				
				L9	17133.0	U33	17217.0
				L10	17136.5	U34	17220.5
				L11	17140.0	U35	17224.0
				L12	17143.5	U36	17227.5
				L13	17147.0	U37	17231.0
				L14	17150.5	U38	17234.5
				L15	17154.0	U39	17238.0
				L16	17157.5	U40	17241.5
				L17	17161.0	U41	17245.0
				L18	17164.5	U42	17248.5
				L19	17168.0	U43	17252.0
				L20	17171.5	U44	17255.5
				L21	17175.0	U45	17259.0
				L22	17178.5	U46	17262.5
				L23	17182.0	U47	17266.0
L24	17185.5	**U48**	17269.5				

ver. 2.1

10.7. RAy2-24 parameters

10.7.1. Upper/Lower Limits

RAy2-24	TX power	
Modulation	Min	Max
	[dBm]	[dBm]
QPSK	-30	10
16-QAM	-30	10
32-QAM	-30	10
64-QAM	-30	10
128-QAM	-30	10
256-QAM	-30	10

ver. 1.0

Minimum (hw limit) and default duplex spacing.

RAy2-24	Optional duplex spacing	
Channel width	min	default
[MHz]	[MHz]	[MHz]
3.5	60	73.5
7	60	73.5
14	65	87.5
28	70	84
40	70	70
50	84	87.5
56	84	84

ver. 2.6

RAy2-24	Band Range	
	Unit L	Unit U
	[MHz]	[MHz]
min	24.000	24.000
max	24.250	24.250

ver. 1.0

10.7.2. Radio parameters

RAy2-24	Channel spacing 3.5 MHz; ACCP operation							
Modula-tion	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	6	4.9	-96	9.5	15 / 23	12 / 19	-14 / 0	-16 / -4
16-QAM	12	9.6	-89	15.0	22 / 30	20 / 26.5	-13 / -3	-15 / -7
32-QAM	15	12.1	-86	18.5	24 / 30	22 / 26.5	-12 / -3	-14 / -7
64-QAM	18	14.3	-83	20.5	29 / 30	26 / 26.5	-11 / -3	-12 / -7
128-QAM	21	17.2	-79	23.5	30 / 30	28 / 26.5	-9 / -3	-8 / -7
256-QAM	24	19.7	-77	26.0	33 / 30	31 / 26.5	-5 / -3	-7 / -7

ver. 1.0

RAy2-24	Channel spacing 7 MHz; ACCP operation							
Modula-tion	**Raw Bit Rate**	**User Bit Rate**	RSS / SNR for BER 10^{-6}		**Co-channel rejection**		**Adjacent channel Selectivity**	
					1 dB	3 dB	1 dB	3 dB
			RSS	**SNR**	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	12	8.5	-93	8.5	15 / 23	12 / 19	-20 / 0	-22 / -4
16-QAM	24	17.2	-86	15.0	22 / 30	20 / 26.5	-18 / -3	-19 / -7
32-QAM	30	22.1	-83	18.5	24 / 37	22 / 33	-16 / -2	-18 / -6
64-QAM	36	29.7	-79	21.5	29 / 37	26 / 33	-14 / -2	-16 / -6
128-QAM	42	34.7	-76	25.0	32 / 37	30 / 33	-12 / -2	-14 / -6
256-QAM	49	40.7	-74	26.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 1.0

RAy2-24	Channel spacing 14 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	24	19.9	-91	8.5	14 / 23	12 / 19	-21 / 0	-23 / -4
16-QAM	48	38.8	-84	15.0	20 / 30	18 / 26.5	-19 / -3	-21 / -7
32-QAM	60	49.1	-80	18.5	26 / 33	23 / 29	-17 / -5	-19 / -9
64-QAM	72	62.3	-77	21.5	28 / 37	26 / 33	-14 / -2	-17 / -6
128-QAM	84	73.6	-73	25.0	30 / 37	28 / 33	-12 / -2	-14 / -6
256-QAM	96	81.2	-71	28.0	33 / 37	31 / 33	-10 / -2	-12 / -6

ver. 1.0

RAy2-24	Channel spacing 28 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	50	36.8	-89	7.5	12 / 23	10 / 19	-21 / 0	-23 / -4
16-QAM	100	80.9	-82	15.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	125	102.4	-78	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	150	129.8	-75	21.5	28 / 35	26 / 32	-12 / -5	-15 / -8
128-QAM	175	155.5	-71	25.0	30 / 35	28 / 32	-9 / -5	-12 / -8
256-QAM	200	170.7	-68	26.5	33 / 35	31 / 32	-6 / -5	-9 / -8

ver. 1.0

RAy2-24	Channel spacing 40 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	68	50.1	-87	7.5	12 / 33	10 / 29	-22 / -4	-24 / -8
16-QAM	136	110.0	-80	15.0	19 / 33	17 / 29	-18 / -4	-21 / -8
32-QAM	170	139.2	-76	18.5	24 / 33	21 / 29	-16 / -4	-19 / -8
64-QAM	204	176.5	-73	21.5	27 / 33	25 / 29	-14 / -4	-16 / -8
128-QAM	238	211.4	-69	25.0	30 / 37	28 / 33	-10 / -4	-12 / -8
256-QAM	272	232.1	-67	26.5	33 / 37	30 / 33	-8 / -4	-10 / -8

ver. 1.1

RAy2-24	Channel spacing 50 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	90	66.3	-86.5	7.5	12 / 23	10 / 19	-24 / 0	-26 / -4
16-QAM	180	145.6	-79.5	15.0	19 / 30	17 / 26.5	-18 / -3	-21 / -7
32-QAM	225	184.2	-75.5	18.5	24 / 33	22 / 29	-16 / -5	-19 / -9
64-QAM	270	233.6	-72.5	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128-QAM	315	276.1	-68.5	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	360	320.6	-65.5	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 1.0

RAy2-24	Channel spacing 56 MHz; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	72.9	-86	7.5	12 / 23	10 / 19	-26 / 0	-28 / -4
16-QAM	198	160.2	-79	15.0	19 / 30	17 / 26.5	-19 / -3	-21 / -7
32-QAM	247.5	202.7	-75	18.5	24 / 33	22 / 29	-15 / -5	-17 / -9
64-QAM	297	256.9	-72	21.5	27 / 35	25 / 32	-14 / -5	-16 / -8
128-QAM	346.5	303.7	-68	25.0	30 / 35	28 / 32	-10 / -5	-12 / -8
256-QAM	396	337.7	-65	26.5	33 / 35	30 / 32	-8 / -5	-10 / -8

ver. 1.0

RAy2-24	Channel spacing 56 MHz TO; ACCP operation							
Modulation	Raw Bit Rate	User Bit Rate	RSS / SNR for BER 10^{-6}		Co-channel rejection		Adjacent channel Selectivity	
					1 dB	3 dB	1 dB	3 dB
			RSS	SNR	declared / limit	declared / limit	declared / limit	declared / limit
[-]	*[Mbps]*		*[dBm]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*	*[dB]*
QPSK	99	85.8	-84	10.0	13 / 23	11 / 19	-24 / 0	-26 / -4
16-QAM	198	169.9	-77	16.0	20 / 30	18 / 26.5	-18 / -3	-20 / -7
32-QAM	247.5	206.2	-73	19.0	25 / 33	23 / 29	-14 / -5	-15 / -9
64-QAM	297	268.1	-69	22.5	29 / 35	26 / 32	-9 / -5	-11 / -8
128-QAM	346.5	309.0	-66	25.5	32 / 35	29 / 32	-8 / -5	-10 / -8
256-QAM	396	358.9	-63	27.5	35 / 35	32 / 32	-7 / -5	-8 / -8

ver. 1.1

10.7.3. Nominal frequencies 24.00-24.25 GHz

RAy2-24 TX channel nominal frequencies

Band 24.00 – 24.25 GHz, duplex spacing 73.5 MHz

Bandwidth: **3.5 MHz** duplex spacing range 63 – 238 MHz

(Freq.table: rcinfo24_ISM250_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U19	24069.0	no more channels			
		U20	24072.5				
		U21	24076.0				
L1	24006.0	**U22**	24079.5				
L2	24009.5	**U23**	24083.0				
L3	24013.0	**U24**	24086.5				
L4	24016.5	**U25**	24090.0				
L5	24020.0	**U26**	24093.5				
L6	24023.5	**U27**	24097.0				
L7	24027.0	**U28**	24100.5				
L8	24030.5	**U29**	24104.0				
L9	24034.0	**U30**	24107.5				
L10	24037.5	**U31**	24111.0				
L11	24041.0	**U32**	24114.5				
L12	24044.5	**U33**	24118.0				
L13	24048.0	**U34**	24121.5				
L14	24051.5	**U35**	24125.0				
L15	24055.0	**U36**	24128.5				
L16	24058.5	**U37**	24132.0				
L17	24062.0	**U38**	24135.5				
L18	24065.5	**U39**	24139.0				
L19	24069.0	**U40**	24142.5				
L20	24072.5	**U41**	24146.0				
L21	24076.0	**U42**	24149.5				
L22	24079.5	**U43**	24153.0				
L23	24083.0	**U44**	24156.5				
L24	24086.5	**U45**	24160.0				
L25	24090.0	**U46**	24163.5				
L26	24093.5	**U47**	24167.0				
L27	24097.0	**U48**	24170.5				
L28	24100.5	**U49**	24174.0				
L29	24104.0	**U50**	24177.5				
L30	24107.5	**U51**	24181.0				
L31	24111.0	**U52**	24184.5				
L32	24114.5	**U53**	24188.0				
L33	24118.0	**U54**	24191.5				
L34	24121.5	**U55**	24195.0				
L35	24125.0	**U56**	24198.5				
L36	24128.5	**U57**	24202.0				
L37	24132.0	**U58**	24205.5				
L38	24135.5	**U59**	24209.0				
L39	24139.0	**U60**	24212.5				
L40	24142.5	**U61**	24216.0				
L41	24146.0	**U62**	24219.5				
L42	24149.5	**U63**	24223.0				
L43	24153.0	**U64**	24226.5				
L44	24156.5	**U65**	24230.0				
L45	24160.0	**U66**	24233.5				
L46	24163.5	**U67**	24237.0				
L47	24167.0	**U68**	24240.5				
L48	24170.5	**U69**	24244.0				
L49	24174.0						
L50	24177.5						
L51	24181.0						

ver. 2.2

RAy2-24 TX channel nominal frequencies

Band 24.00 – 24.25 GHz, duplex spacing 73.5 MHz

Bandwidth: **7 MHz** duplex spacing range 63 – 238 MHz

(Freq.table: rcinfo24_ISM250_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U19	24069.0			U20	24072.5
		U21	24076.0	L1	24006.0	U22	24079.5
L2	24009.5	**U23**	24083.0	L3	24013.0	U24	24086.5
L4	24016.5	**U25**	24090.0	L5	24020.0	U26	24093.5
L6	24023.5	**U27**	24097.0	L7	24027.0	U28	24100.5
L8	24030.5	**U29**	24104.0	L9	24034.0	U30	24107.5
L10	24037.5	**U31**	24111.0	L11	24041.0	U32	24114.5
L12	24044.5	**U33**	24118.0	L13	24048.0	U34	24121.5
L14	24051.5	**U35**	24125.0	L15	24055.0	U36	24128.5
L16	24058.5	**U37**	24132.0	L17	24062.0	U38	24135.5
L18	24065.5	**U39**	24139.0	L19	24069.0	U40	24142.5
L20	24072.5	**U41**	24146.0	L21	24076.0	U42	24149.5
L22	24079.5	**U43**	24153.0	L23	24083.0	U44	24156.5
L24	24086.5	**U45**	24160.0	L25	24090.0	U46	24163.5
L26	24093.5	**U47**	24167.0	L27	24097.0	U48	24170.5
L28	24100.5	**U49**	24174.0	L29	24104.0	U50	24177.5
L30	24107.5	**U51**	24181.0	L31	24111.0	U52	24184.5
L32	24114.5	**U53**	24188.0	L33	24118.0	U54	24191.5
L34	24121.5	**U55**	24195.0	L35	24125.0	U56	24198.5
L36	24128.5	**U57**	24202.0	L37	24132.0	U58	24205.5
L38	24135.5	**U59**	24209.0	L39	24139.0	U60	24212.5
L40	24142.5	**U61**	24216.0	L41	24146.0	U62	24219.5
L42	24149.5	**U63**	24223.0	L43	24153.0	U64	24226.5
L44	24156.5	**U65**	24230.0	L45	24160.0	U66	24233.5
L46	24163.5	**U67**	24237.0	L47	24167.0	U68	24240.5
L48	24170.5	**U69**	24244.0	L49	24174.0		
L50	24177.5			L51	24181.0		

ver. 2.1

RAy2-24 TX channel nominal frequencies

Band 24.00 – 24.25 GHz, duplex spacing 87.5 MHz

Bandwidth: **14 MHz** duplex spacing range 66.5 – 231 MHz

(Freq.table: rcinfo24_ISM250_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U21	24076.0
						U22	24079.5
						U23	24083.0
		U24	24086.5				
						U25	24090.0
						U26	24093.5
				L2	24009.5	U27	24097.0
L3	24013.0	**U28**	24100.5				
				L4	24016.5	U29	24104.0
				L5	24020.0	U30	24107.5
				L6	24023.5	U31	24111.0
L7	24027.0	**U32**	24114.5				
				L8	24030.5	U33	24118.0
				L9	24034.0	U34	24121.5
				L10	24037.5	U35	24125.0
L11	24041.0	**U36**	24128.5				
				L12	24044.5	U37	24132.0
				L13	24048.0	U38	24135.5
				L14	24051.5	U39	24139.0
L15	24055.0	**U40**	24142.5				
				L16	24058.5	U41	24146.0
				L17	24062.0	U42	24149.5
				L18	24065.5	U43	24153.0
L19	24069.0	**U44**	24156.5				
				L20	24072.5	U45	24160.0
				L21	24076.0	U46	24163.5
				L22	24079.5	U47	24167.0
L23	24083.0	**U48**	24170.5				
				L24	24086.5	U49	24174.0
				L25	24090.0	U50	24177.5
				L26	24093.5	U51	24181.0
L27	24097.0	**U52**	24184.5				
				L28	24100.5	U53	24188.0
				L29	24104.0	U54	24191.5
				L30	24107.5	U55	24195.0
L31	24111.0	**U56**	24198.5				
				L32	24114.5	U57	24202.0
				L33	24118.0	U58	24205.5
				L34	24121.5	U59	24209.0
L35	24125.0	**U60**	24212.5				
				L36	24128.5	U61	24216.0
				L37	24132.0	U62	24219.5
				L38	24135.5	U63	24223.0
L39	24139.0	**U64**	24226.5				
				L40	24142.5	U65	24230.0
				L41	24146.0	U66	24233.5
				L42	24149.5	U67	24237.0
L43	24153.0	**U68**	24240.5				
				L44	24156.5		
				L45	24160.0		
				L46	24163.5		
L47	24167.0						
				L48	24170.5		
				L49	24174.0		

ver. 2.1

RAy2-24

TX channel nominal frequencies

Band 24.00 – 24.25 GHz, duplex spacing 84 MHz

Bandwidth: **28 MHz**

duplex spacing range 70 – 217 MHz

(Freq.table: rcinfo24_ISM250_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U24	24086.5
						U25	24090.0
		U26	24093.5				
						U27	24097.0
				L4	24016.5	U28	24100.5
				L5	24020.0	U29	24104.0
				L6	24023.5	U30	24107.5
				L7	24027.0	U31	24111.0
				L8	24030.5	U32	24114.5
				L9	24034.0	U33	24118.0
L10	24037.5	**U34**	24121.5				
				L11	24041.0	U35	24125.0
				L12	24044.5	U36	24128.5
				L13	24048.0	U37	24132.0
				L14	24051.5	U38	24135.5
				L15	24055.0	U39	24139.0
				L16	24058.5	U40	24142.5
				L17	24062.0	U41	24146.0
L18	24065.5	**U42**	24149.5				
				L19	24069.0	U43	24153.0
				L20	24072.5	U44	24156.5
				L21	24076.0	U45	24160.0
				L22	24079.5	U46	24163.5
				L23	24083.0	U47	24167.0
				L24	24086.5	U48	24170.5
				L25	24090.0	U49	24174.0
L26	24093.5	**U50**	24177.5				
				L27	24097.0	U51	24181.0
				L28	24100.5	U52	24184.5
				L29	24104.0	U53	24188.0
				L30	24107.5	U54	24191.5
				L31	24111.0	U55	24195.0
				L32	24114.5	U56	24198.5
				L33	24118.0	U57	24202.0
L34	24121.5	**U58**	24205.5				
				L35	24125.0	U59	24209.0
				L36	24128.5	U60	24212.5
				L37	24132.0	U61	24216.0
				L38	24135.5	U62	24219.5
				L39	24139.0	U63	24223.0
				L40	24142.5	U64	24226.5
				L41	24146.0	U65	24230.0
L42	24149.5	**U66**	24233.5				
				L43	24153.0		
				L44	24156.5		
				L45	24160.0		
				L46	24163.5		

ver. 2.1

RAy2-24

TX channel nominal frequencies

Band 24.00 – 24.25 GHz, duplex spacing 70 MHz

Bandwidth: **40 MHz** duplex spacing range 70 – 203 MHz

(Freq.table: rcinfo24_ISM250_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
				L6	24023.5	U26	24093.5
				L7	24027.0	U27	24097.0
L8	24030.5	**U28**	24100.5				
				L9	24034.0	U29	24104.0
				L10	24037.5	U30	24107.5
				L11	24041.0	U31	24111.0
				L12	24044.5	U32	24114.5
				L13	24048.0	U33	24118.0
				L14	24051.5	U34	24121.5
				L15	24055.0	U35	24125.0
				L16	24058.5	U36	24128.5
				L17	24062.0	U37	24132.0
				L18	24065.5	U38	24135.5
				L19	24069.0	U39	24139.0
L20	24072.5	**U40**	24142.5				
				L21	24076.0	U41	24146.0
				L22	24079.5	U42	24149.5
				L23	24083.0	U43	24153.0
				L24	24086.5	U44	24156.5
				L25	24090.0	U45	24160.0
				L26	24093.5	U46	24163.5
				L27	24097.0	U47	24167.0
				L28	24100.5	U48	24170.5
				L29	24104.0	U49	24174.0
				L30	24107.5	U50	24177.5
				L31	24111.0	U51	24181.0
L32	24114.5	**U52**	24184.5				
				L33	24118.0	U53	24188.0
				L34	24121.5	U54	24191.5
				L35	24125.0	U55	24195.0
				L36	24128.5	U56	24198.5
				L37	24132.0	U57	24202.0
				L38	24135.5	U58	24205.5
				L39	24139.0	U59	24209.0
				L40	24142.5	U60	24212.5
				L41	24146.0	U61	24216.0
				L42	24149.5	U62	24219.5
				L43	24153.0	U63	24223.0
L44	24156.5	**U64**	24226.5				

ver. 2.1

RAy2-24

TX channel nominal frequencies

Band 24.00 – 24.25 GHz, duplex spacing 87.5 MHz

Bandwidth: **50 MHz**

duplex spacing range 84 – 196 MHz

(Freq.table: rcinfo24_ISM250_default:15)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U31	24111.0
				L7	24027.0	U32	24114.5
L8	24030.5	**U33**	24118.0				
				L9	24034.0	U34	24121.5
				L10	24037.5	U35	24125.0
				L11	24041.0	U36	24128.5
				L12	24044.5	U37	24132.0
				L13	24048.0	U38	24135.5
				L14	24051.5	U39	24139.0
				L15	24055.0	U40	24142.5
				L16	24058.5	U41	24146.0
				L17	24062.0	U42	24149.5
				L18	24065.5	U43	24153.0
				L19	24069.0	U44	24156.5
				L20	24072.5	U45	24160.0
				L21	24076.0	U46	24163.5
				L22	24079.5	U47	24167.0
L23	24083.0	**U48**	24170.5				
				L24	24086.5	U49	24174.0
				L25	24090.0	U50	24177.5
				L26	24093.5	U51	24181.0
				L27	24097.0	U52	24184.5
				L28	24100.5	U53	24188.0
				L29	24104.0	U54	24191.5
				L30	24107.5	U55	24195.0
				L31	24111.0	U56	24198.5
				L32	24114.5	U57	24202.0
				L33	24118.0	U58	24205.5
				L34	24121.5	U59	24209.0
				L35	24125.0	U60	24212.5
				L36	24128.5	U61	24216.0
				L37	24132.0	U62	24219.5
L38	24135.5	**U63**	24223.0				
				L39	24139.0		

ver. 1.0

RAy2-24

TX channel nominal frequencies

Band 24.00 – 24.25 GHz, duplex spacing 84 MHz

Bandwidth: **56 MHz**

duplex spacing range 84 – 189 MHz

(Freq.table: rcinfo24_ISM250_default:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
				L8	24030.5	U32	24114.5
				L9	24034.0	U33	24118.0
				L10	24037.5	U34	24121.5
				L11	24041.0	U35	24125.0
				L12	24044.5	U36	24128.5
				L13	24048.0	U37	24132.0
				L14	24051.5	U38	24135.5
				L15	24055.0	U39	24139.0
				L16	24058.5	U40	24142.5
				L17	24062.0	U41	24146.0
				L18	24065.5	U42	24149.5
				L19	24069.0	U43	24153.0
				L20	24072.5	U44	24156.5
				L21	24076.0	U45	24160.0
L22	24079.5	**U46**	24163.5				
				L23	24083.0	U47	24167.0
				L24	24086.5	U48	24170.5
				L25	24090.0	U49	24174.0
				L26	24093.5	U50	24177.5
				L27	24097.0	U51	24181.0
				L28	24100.5	U52	24184.5
				L29	24104.0	U53	24188.0
				L30	24107.5	U54	24191.5
				L31	24111.0	U55	24195.0
				L32	24114.5	U56	24198.5
				L33	24118.0	U57	24202.0
				L34	24121.5	U58	24205.5
				L35	24125.0	U59	24209.0
				L36	24128.5	U60	24212.5
				L37	24132.0	U61	24216.0
L38	24135.5	**U62**	24219.5				

ver. 2.1

10.7.4. Nominal frequencies 24.05-24.25 GHz

RAy2-24 TX channel nominal frequencies
Band 24.05 – 24.25 GHz, default duplex sp. 73.5 MHz

Bandwidth: **3.5 MHz** duplex spacing range 63 – 189 MHz

(Freq.table: rcinfo24_ISM200:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U33	24118.0	no more channels			
		U34	24121.5				
		U35	24125.0				
L15	24055.0	**U36**	24128.5				
L16	24058.5	**U37**	24132.0				
L17	24062.0	**U38**	24135.5				
L18	24065.5	**U39**	24139.0				
L19	24069.0	**U40**	24142.5				
L20	24072.5	**U41**	24146.0				
L21	24076.0	**U42**	24149.5				
L22	24079.5	**U43**	24153.0				
L23	24083.0	**U44**	24156.5				
L24	24086.5	**U45**	24160.0				
L25	24090.0	**U46**	24163.5				
L26	24093.5	**U47**	24167.0				
L27	24097.0	**U48**	24170.5				
L28	24100.5	**U49**	24174.0				
L29	24104.0	**U50**	24177.5				
L30	24107.5	**U51**	24181.0				
L31	24111.0	**U52**	24184.5				
L32	24114.5	**U53**	24188.0				
L33	24118.0	**U54**	24191.5				
L34	24121.5	**U55**	24195.0				
L35	24125.0	**U56**	24198.5				
L36	24128.5	**U57**	24202.0				
L37	24132.0	**U58**	24205.5				
L38	24135.5	**U59**	24209.0				
L39	24139.0	**U60**	24212.5				
L40	24142.5	**U61**	24216.0				
L41	24146.0	**U62**	24219.5				
L42	24149.5	**U63**	24223.0				
L43	24153.0	**U64**	24226.5				
L44	24156.5	**U65**	24230.0				
L45	24160.0	**U66**	24233.5				
L46	24163.5	**U67**	24237.0				
L47	24167.0	**U68**	24240.5				
L48	24170.5	**U69**	24244.0				
L49	24174.0						
L50	24177.5						
L51	24181.0						

ver. 2.2

RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. 73.5 MHz

Bandwidth: **7 MHz**

duplex spacing range 63 – 189 MHz

(Freq.table: rcinfo24_ISM200:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U33	24118.0				
						U34	24121.5
		U35	24125.0				
				L15	24055.0	U36	24128.5
L16	24058.5	**U37**	24132.0				
				L17	24062.0	U38	24135.5
L18	24065.5	**U39**	24139.0				
				L19	24069.0	U40	24142.5
L20	24072.5	**U41**	24146.0				
				L21	24076.0	U42	24149.5
L22	24079.5	**U43**	24153.0				
				L23	24083.0	U44	24156.5
L24	24086.5	**U45**	24160.0				
				L25	24090.0	U46	24163.5
L26	24093.5	**U47**	24167.0				
				L27	24097.0	U48	24170.5
L28	24100.5	**U49**	24174.0				
				L29	24104.0	U50	24177.5
L30	24107.5	**U51**	24181.0				
				L31	24111.0	U52	24184.5
L32	24114.5	**U53**	24188.0				
				L33	24118.0	U54	24191.5
L34	24121.5	**U55**	24195.0				
				L35	24125.0	U56	24198.5
L36	24128.5	**U57**	24202.0				
				L37	24132.0	U58	24205.5
L38	24135.5	**U59**	24209.0				
				L39	24139.0	U60	24212.5
L40	24142.5	**U61**	24216.0				
				L41	24146.0	U62	24219.5
L42	24149.5	**U63**	24223.0				
				L43	24153.0	U64	24226.5
L44	24156.5	**U65**	24230.0				
				L45	24160.0	U66	24233.5
L46	24163.5	**U67**	24237.0				
				L47	24167.0	U68	24240.5
L48	24170.5	**U69**	24244.0				
				L49	24174.0		
L50	24177.5						
				L51	24181.0		

ver. 2.1

RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. 87.5 MHz

Bandwidth: **14 MHz**

duplex spacing range 66.5 – 182 MHz

(Freq.table: rcinfo24_ISM200:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U35	24125.0
		U36	24128.5				
						U37	24132.0
						U38	24135.5
						U39	24139.0
		U40	24142.5				
				L16	24058.5	U41	24146.0
				L17	24062.0	U42	24149.5
				L18	24065.5	U43	24153.0
L19	24069.0	**U44**	24156.5				
				L20	24072.5	U45	24160.0
				L21	24076.0	U46	24163.5
				L22	24079.5	U47	24167.0
L23	24083.0	**U48**	24170.5				
				L24	24086.5	U49	24174.0
				L25	24090.0	U50	24177.5
				L26	24093.5	U51	24181.0
L27	24097.0	**U52**	24184.5				
				L28	24100.5	U53	24188.0
				L29	24104.0	U54	24191.5
				L30	24107.5	U55	24195.0
L31	24111.0	**U56**	24198.5				
				L32	24114.5	U57	24202.0
				L33	24118.0	U58	24205.5
				L34	24121.5	U59	24209.0
L35	24125.0	**U60**	24212.5				
				L36	24128.5	U61	24216.0
				L37	24132.0	U62	24219.5
				L38	24135.5	U63	24223.0
L39	24139.0	**U64**	24226.5				
				L40	24142.5	U65	24230.0
				L41	24146.0	U66	24233.5
				L42	24149.5	U67	24237.0
L43	24153.0	**U68**	24240.5				
				L44	24156.5		
				L45	24160.0		
				L46	24163.5		
L47	24167.0						
				L48	24170.5		
				L49	24174.0		

ver. 2.1

RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. 84 MHz

Bandwidth: **28 MHz**

duplex spacing range 70 – 168 MHz

(Freq.table: rcinfo24_ISM200:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U38	24135.5
						U39	24139.0
						U40	24142.5
						U41	24146.0
L18	24065.5	**U42**	24149.5				
				L19	24069.0	U43	24153.0
				L20	24072.5	U44	24156.5
				L21	24076.0	U45	24160.0
				L22	24079.5	U46	24163.5
				L23	24083.0	U47	24167.0
				L24	24086.5	U48	24170.5
				L25	24090.0	U49	24174.0
L26	24093.5	**U50**	24177.5				
				L27	24097.0	U51	24181.0
				L28	24100.5	U52	24184.5
				L29	24104.0	U53	24188.0
				L30	24107.5	U54	24191.5
				L31	24111.0	U55	24195.0
				L32	24114.5	U56	24198.5
				L33	24118.0	U57	24202.0
L34	24121.5	**U58**	24205.5				
				L35	24125.0	U59	24209.0
				L36	24128.5	U60	24212.5
				L37	24132.0	U61	24216.0
				L38	24135.5	U62	24219.5
				L39	24139.0	U63	24223.0
				L40	24142.5	U64	24226.5
				L41	24146.0	U65	24230.0
L42	24149.5	**U66**	24233.5				
				L43	24153.0		
				L44	24156.5		
				L45	24160.0		
				L46	24163.5		

ver. 2.1

RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. 70 MHz

Bandwidth: **40 MHz**

duplex spacing range 70 – 154 MHz

(Freq.table: rcinfo24_ISM200:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L20	24072.5	**U40**	24142.5				
				L21	24076.0	U41	24146.0
				L22	24079.5	U42	24149.5
				L23	24083.0	U43	24153.0
				L24	24086.5	U44	24156.5
				L25	24090.0	U45	24160.0
				L26	24093.5	U46	24163.5
				L27	24097.0	U47	24167.0
				L28	24100.5	U48	24170.5
				L29	24104.0	U49	24174.0
				L30	24107.5	U50	24177.5
				L31	24111.0	U51	24181.0
L32	24114.5	**U52**	24184.5				
				L33	24118.0	U53	24188.0
				L34	24121.5	U54	24191.5
				L35	24125.0	U55	24195.0
				L36	24128.5	U56	24198.5
				L37	24132.0	U57	24202.0
				L38	24135.5	U58	24205.5
				L39	24139.0	U59	24209.0
				L40	24142.5	U60	24212.5
				L41	24146.0	U61	24216.0
				L42	24149.5	U62	24219.5
				L43	24153.0	U63	24223.0
L44	24156.5	**U64**	24226.5				

ver. 2.1

RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. 87.5 MHz

Bandwidth: **50 MHz**

duplex spacing range 84 – 143.5 MHz

(Freq.table: rcinfo24_ISM200:14)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U46	24163.5
				L22	24079.5	U47	24167.0
L23	24083.0	**U48**	24170.5				
				L24	24086.5	U49	24174.0
				L25	24090.0	U50	24177.5
				L26	24093.5	U51	24181.0
				L27	24097.0	U52	24184.5
				L28	24100.5	U53	24188.0
				L29	24104.0	U54	24191.5
				L30	24107.5	U55	24195.0
				L31	24111.0	U56	24198.5
				L32	24114.5	U57	24202.0
				L33	24118.0	U58	24205.5
				L34	24121.5	U59	24209.0
				L35	24125.0	U60	24212.5
				L36	24128.5	U61	24216.0
				L37	24132.0	U62	24219.5
L38	24135.5	**U63**	24223.0				
				L39	24139.0		

ver. 1.1

RAy2-24

TX channel nominal frequencies

Band 24.05 – 24.25 GHz, default duplex sp. 84 MHz

Bandwidth: **56 MHz**

duplex spacing range 84 – 140 MHz

(Freq.table: rcinfo24_ISM200:13)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L22	24079.5	**U46**	24163.5				
				L23	24083.0	U47	24167.0
				L24	24086.5	U48	24170.5
				L25	24090.0	U49	24174.0
				L26	24093.5	U50	24177.5
				L27	24097.0	U51	24181.0
				L28	24100.5	U52	24184.5
				L29	24104.0	U53	24188.0
				L30	24107.5	U54	24191.5
				L31	24111.0	U55	24195.0
				L32	24114.5	U56	24198.5
				L33	24118.0	U57	24202.0
				L34	24121.5	U58	24205.5
				L35	24125.0	U59	24209.0
				L36	24128.5	U60	24212.5
				L37	24132.0	U61	24216.0
L38	24135.5	**U62**	24219.5				

ver. 2.1

10.7.5. Nominal frequencies 24.00-24.15 GHz

RAy2-24 TX channel nominal frequencies
Band 24.00 – 24.15 GHz, duplex spacing 73.5 MHz

Bandwidth: **3.5 MHz** duplex spacing range 63 – 140 MHz

(Freq.table: rcinfo24_ISM150:1)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
		U19	24069.0	no more channels			
		U20	24072.5				
		U21	24076.0				
L1	24006.0	**U22**	24079.5				
L2	24009.5	**U23**	24083.0				
L3	24013.0	**U24**	24086.5				
L4	24016.5	**U25**	24090.0				
L5	24020.0	**U26**	24093.5				
L6	24023.5	**U27**	24097.0				
L7	24027.0	**U28**	24100.5				
L8	24030.5	**U29**	24104.0				
L9	24034.0	**U30**	24107.5				
L10	24037.5	**U31**	24111.0				
L11	24041.0	**U32**	24114.5				
L12	24044.5	**U33**	24118.0				
L13	24048.0	**U34**	24121.5				
L14	24051.5	**U35**	24125.0				
L15	24055.0	**U36**	24128.5				
L16	24058.5	**U37**	24132.0				
L17	24062.0	**U38**	24135.5				
L18	24065.5	**U39**	24139.0				
L19	24069.0	**U40**	24142.5				
L20	24072.5	**U41**	24146.0				
L21	24076.0						
L22	24079.5						
L23	24083.0						

ver. 1.0

RAy2-24

TX channel nominal frequencies

Band 24.00 – 24.15 GHz, duplex spacing 73.5 MHz

Bandwidth: **7 MHz**

duplex spacing range 63 – 136.5 MHz

(Freq.table: rcinfo24_ISM150:1)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U19	24069
		U20	24072.5				
						U21	24076
L1	24006.0	**U22**	24079.5				
				L2	24009.5	U23	24083
L3	24013.0	**U24**	24086.5				
				L4	24016.5	U25	24090
L5	24020.0	**U26**	24093.5				
				L6	24023.5	U27	24097
L7	24027.0	**U28**	24100.5				
				L8	24030.5	U29	24104
L9	24034.0	**U30**	24107.5				
				L10	24037.5	U31	24111
L11	24041.0	**U32**	24114.5				
				L12	24044.5	U33	24118
L13	24048.0	**U34**	24121.5				
				L14	24051.5	U35	24125
L15	24055.0	**U36**	24128.5				
				L16	24058.5	U37	24132
L17	24062.0	**U38**	24135.5				
				L18	24065.5	U39	24139
L19	24069.0	**U40**	24142.5				
				L20	24072.5		
L21	24076.0						
				L22	24079.5		

ver. 1.0

RAy2-24

TX channel nominal frequencies
Band 24.00 – 24.15 GHz, duplex spacing 87.5 MHz

Bandwidth: **14 MHz**

duplex spacing range 66.5 – 129.5 MHz

(Freq.table: rcinfo24_ISM150:1)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U21	24076.0
						U22	24079.5
		U23	24083				
						U24	24086.5
						U25	24090.0
						U26	24093.5
L2	24009.5	**U27**	24097				
				L3	24013.0	U28	24100.5
				L4	24016.5	U29	24104.0
				L5	24020.0	U30	24107.5
L6	24023.5	**U31**	24111				
				L7	24027.0	U32	24114.5
				L8	24030.5	U33	24118.0
				L9	24034.0	U34	24121.5
L10	24037.5	**U35**	24125				
				L11	24041.0	U36	24128.5
				L12	24044.5	U37	24132.0
				L13	24048.0	U38	24135.5
L14	24051.5	**U39**	24139				
				L15	24055.0		
				L16	24058.5		
				L17	24062.0		
L18	24065.5						
				L19	24069.0		
				L20	24072.5		

ver. 1.0

RAy2-24

TX channel nominal frequencies

Band 24.00 – 24.15 GHz, duplex spacing 84 MHz

Bandwidth: **28 MHz**

duplex spacing range 70 – 115.5 MHz

(Freq.table: rcinfo24_ISM150:1)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
						U24	24086.5
						U25	24090.0
						U26	24093.5
						U27	24097.0
L4	24016.5	**U28**	24100.5				
				L5	24020.0	U29	24104.0
				L6	24023.5	U30	24107.5
				L7	24027.0	U31	24111.0
				L8	24030.5	U32	24114.5
				L9	24034.0	U33	24118.0
				L10	24037.5	U34	24121.5
				L11	24041.0	U35	24125.0
L12	24044.5	**U36**	24128.5				
				L13	24048.0	U37	24132.0
				L14	24051.5		
				L15	24055.0		
				L16	24058.5		
				L17	24062.0		

ver. 1.0

RAy2-24

TX channel nominal frequencies

Band 24.00 – 24.15 GHz, duplex spacing 70 MHz

Bandwidth: **40 MHz**

duplex spacing range 70 – 105 MHz

(Freq.table: rcinfo24_ISM150:1)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
				L6	24023.5	U26	24093.5
L7	24027.0	**U27**	24097.0				
				L8	24030.5	U28	24100.5
				L9	24034.0	U29	24104.0
				L10	24037.5	U30	24107.5
				L11	24041.0	U31	24111.0
				L12	24044.5	U32	24114.5
				L13	24048.0	U33	24118.0
				L14	24051.5	U34	24121.5
				L15	24055.0	U35	24125.0
				L16	24058.5	U36	24128.5

ver. 1.0

RAy2-24 TX channel nominal frequencies
Band 24.00 – 24.15 GHz, duplex spacing 87.5 MHz

Bandwidth: **50 MHz** duplex spacing range 84 – 94.5 MHz

(Freq.table: rcinfo24_ISM150:2)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L8	24030.5	**U33**	24118.0	L7	24027.0	U31	24111.0
						U32	24114.5
				L9	24034.0	U34	24121.5
				L10	24037.5		

ver. 1.0

RAy2-24 TX channel nominal frequencies
Band 24.00 – 24.15 GHz, duplex spacing 84 MHz

Bandwidth: **56 MHz** duplex spacing range 84 – 87.5 MHz

(Freq.table: rcinfo24_ISM150:1)

basic channels (default duplex)				optional channels			
Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]	Ch.No.	Lower [MHz]	Ch.No.	Upper [MHz]
L9	24034.0	**U33**	24118.0	L8	24030.5	U32	24114.5

ver. 1.0

All technical parameters within this User manual are subject to change without prior notification.

11. Safety, environment, licensing

11.1. Frequency

RAy2 microwave links designed for operation in licensed bands must be used in accordance with license issued by the Telecommunications Authority for the area the device is operating in.

RAy2 microwave links must comply with the maximum permitted radiated power (EIRP) in accordance with conditions of the given country.

11.2. RoHS and WEEE compliance

The RAy2 is fully compliant with the European Commission‟s RoHS (Restriction of Certain Hazardous Substances in Electrical and Electronic Equipment) and WEEE (Waste Electrical and Electronic Equipment) environmental directives.

RoHS Restriction of hazardous substances (RoHS)

The RoHS Directive prohibits the sale in the European Union of electronic equipment containing these hazardous substances: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBBs), and polybrominated diphenyl ethers (PBDEs).

End-of-life recycling programme (WEEE)

The WEEE Directive is concerned with the recovery, reuse, and recycling of electronic and electrical equipment. Under the Directive, used equipment must be marked, collected separately, and disposed of properly. Racom has instigated a programme to manage the reuse, recycling, and recovery of waste in an environmentally safe manner using processes that comply with the WEEE Directive (EU Waste Electrical and Electronic Equipment 2002/96/EC).

Battery Disposal —This product may contain a battery. Batteries must be disposed of properly, and may not be disposed of as unsorted municipal waste within the European Union. See the product documentation for specific battery information. Batteries are marked with a symbol, which may include lettering to indicate cadmium (Cd), lead (Pb), or mercury (Hg). For proper recycling, return the battery to your supplier or to a designated collection point.

11.3. Liability for Defects and Safety Instructions

Please read these safety instructions carefully before using the product:

- Liability for defects does not apply to any product that has been used in a manner that conflicts with the instructions contained in this operator manual, if the case in which the radio modem is packed has been opened, or if the equipment has been tampered with.
- The radio equipment can only be operated on frequencies stipulated by the body authorised by the radio operation administration in the respective country and cannot exceed the maximum permitted output power. RACOM is not responsible for products used in an unauthorised way.
- Equipment mentioned in this operator manual may only be used in accordance with instructions contained in this manual. Error-free and safe operation of this equipment is only guaranteed if this

equipment is transported, stored, operated and controlled in the proper manner. The same applies to equipment maintenance.

- In order to prevent damage to the radio modem and other terminal equipment the supply must always be disconnected upon connecting or disconnecting the cable to the radio modem data interface. It is necessary to ensure that connected equipment has been grounded to the same potential.
- Only the undermentioned manufacturer is entitled to repair any devices.
- Should the RAy2 unit be used with accessories other than those recommended, Racom takes no responsibility for any malfunction caused by the use of such accessories. Using unsuitable accessories (e.g.cable connectors) can result in mechanical damage to RAy2 internal connectors, allow the penetration of water inside the unit, or reduce the efficiency of internal surge protection circuits.

11.4. Important Notifications

RACOM reserves the right to make changes to the technical specification, in the product function, to terminate production of this product or to terminate its service support without previous written notification of customers.

Conditions of use of this product software abide by the license mentioned below. The program distributed by this license has been freed with the purpose to be useful, but without any specific guarantee. Under no circumstances is the author or another company or person responsible for secondary, accidental or related damages resulting from application of this product.

The producer does not provide the user with any kind of guarantee providing assurances of suitability and usability for his application. Products are not developed, designed or tested for utilization in devices directly affecting the health or life functions of persons or animals, nor as a part of another important device, and does not provide guarantees if the product has been used in these aforementioned devices.

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Version 1.0, November 2009

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11.5. Warranty

RACOM supplied parts or equipment ("equipment") are covered under warranty for inherently faulty parts and workmanship for a warranty period as stated in the delivery documentation from the date of dispatch to the customer. The warranty does not cover custom modifications to software. During the warranty period RACOM shall, on its option, fit, repair or replace ("service") faulty equipment, always provided that malfunction has occurred during normal use, not due to improper use, whether deliberate or accidental, such as attempted repair or modification by any unauthorised person; nor due to the action of abnormal or extreme environmental conditions such as overvoltage, liquid immersion or lightning strike.

Any equipment subject to repair under warranty must be returned by prepaid freight to RACOM direct. The serviced equipment shall be returned by RACOM to the customer by prepaid freight. If circumstances do not permit the equipment to be returned to RACOM, then the customer is liable and agrees to reimburse RACOM for expenses incurred by RACOM during servicing the equipment on site. When equipment does not qualify for servicing under warranty, RACOM shall charge the customer and be reimbursed for costs incurred for parts and labour at prevailing rates.

This warranty agreement represents the full extent of the warranty cover provided by RACOM to the customer, as an agreement freely entered into by both parties.

RACOM warrants the equipment to function as described, without guaranteeing it as befitting customer intent or purpose. Under no circumstances shall RACOM's liability extend beyond the above, nor shall RACOM, its principals, servants or agents be liable for any consequential loss or damage caused directly or indirectly through the use, misuse, function or malfunction of the equipment, always subject to such statutory protection as may explicitly and unavoidably apply hereto.

11.6. Declaration of Conformity

RACOM
RADIO DATA NETWORKS

Declaration of Conformity RAy2-10

We

Manufacturer: **RACOM**

Address: **Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**

VAT: **CZ46343423**

declare under our own responsibility that the product

Product: **RAy2-10** **sub-band A** (10 300 – 10 420 MHz; 10 470 – 10 590 MHz)
sub-band B (10 125 – 10 325 MHz; 10 475 – 10 675 MHz)

Purpose of use: **Microwave IP Bridge**

to which this declaration relates is in conformity with the essential requirements and other relevant requirements of the Directive of the European Parliament and of the Council 1999/5/EC on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

The product is in conformity with the following standards and/or other normative documents:

Spectrum (art 3.2)	EN 302 217-1 V1.3.1
	EN 302 217-2-2 V2.2.1
EMC (art 3.1.b)	EN 301 489-1 V1.9.2
	EN 301 489-4 V2.1.1
Safety (art 3.1.a)	EN 60950-1 ed.2:2006, +A1:2010, +A2:2014, +A11:2009, +A12:2011, +Cor.1:2012

Notified Body Opinion:

According to:	European Union Directive 1999/5/EC – ANNEX IV
Document No.:	0120-CC-V0030-14
Issued by:	Cesky metrologicky institut, Okruzni 31, Brno, CR, 13th of February 2015
Notified Body:	No. 1383

CE 1383 ⓘ

The above named equipment is classified as a Class 2 radio equipment and it is marked with Equipment Class Identifier ⓘ in accordance with Commission Decision 2000/299/EC.

Nove Mesto na Morave, 5th of March 2015
Jiri Hruska, CEO

RACOM s.r.o. • Mirova 1283 • 592 31 Nove Mesto na Morave • Czech Republic
Tel.: +420 565 659 511 • Fax: +420 565 659 512 • E-mail: racom@racom.eu

www.racom.eu

ver. 1.3

Fig. 11.1: Declaration of Conformity for RAy2-10

RACOM
RADIO DATA NETWORKS

Declaration of Conformity RAy2-11

We

Manufacturer: **RACOM**
Address: **Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**
VAT: **CZ46343423**

declare under our own responsibility that the product

Product: **RAy2-11** **sub-band A** (10 695 – 10 970 MHz; 11 185 – 11 460 MHz)
sub-band B (10 935 – 11 195 MHz; 11 425 – 11 695 MHz)

Purpose of use: **Microwave IP Bridge**

to which this declaration relates is in conformity with the essential requirements and other relevant requirements of the Directive of the European Parliament and of the Council 1999/5/EC on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

The product is in conformity with the following standards and/or other normative documents:

Spectrum (art 3.2)	EN 302 217-2-2 V2.2.1
EMC (art 3.1.b)	EN 301 489-1 V1.9.2
	EN 301 489-4 V2.1.1
Safety (art 3.1.a)	EN 60950-1 ed.2:2006, +A1:2010, +A2:2014, +A11:2009, +A12:2011, +Cor.1:2012

Notified Body Opinion:

According to:	European Union Directive 1999/5/EC – ANNEX IV
Document No.:	0120-CC-V0001-15
Issued by:	Cesky metrologicky institut, Okruzni 31, Brno, CR, 5th of March 2015
Notified Body:	No. 1383

CE 1383 ⓘ

The above named equipment is classified as a Class 2 radio equipment and it is marked with Equipment Class Identifier ⓘ in accordance with Commission Decision 2000/299/EC.

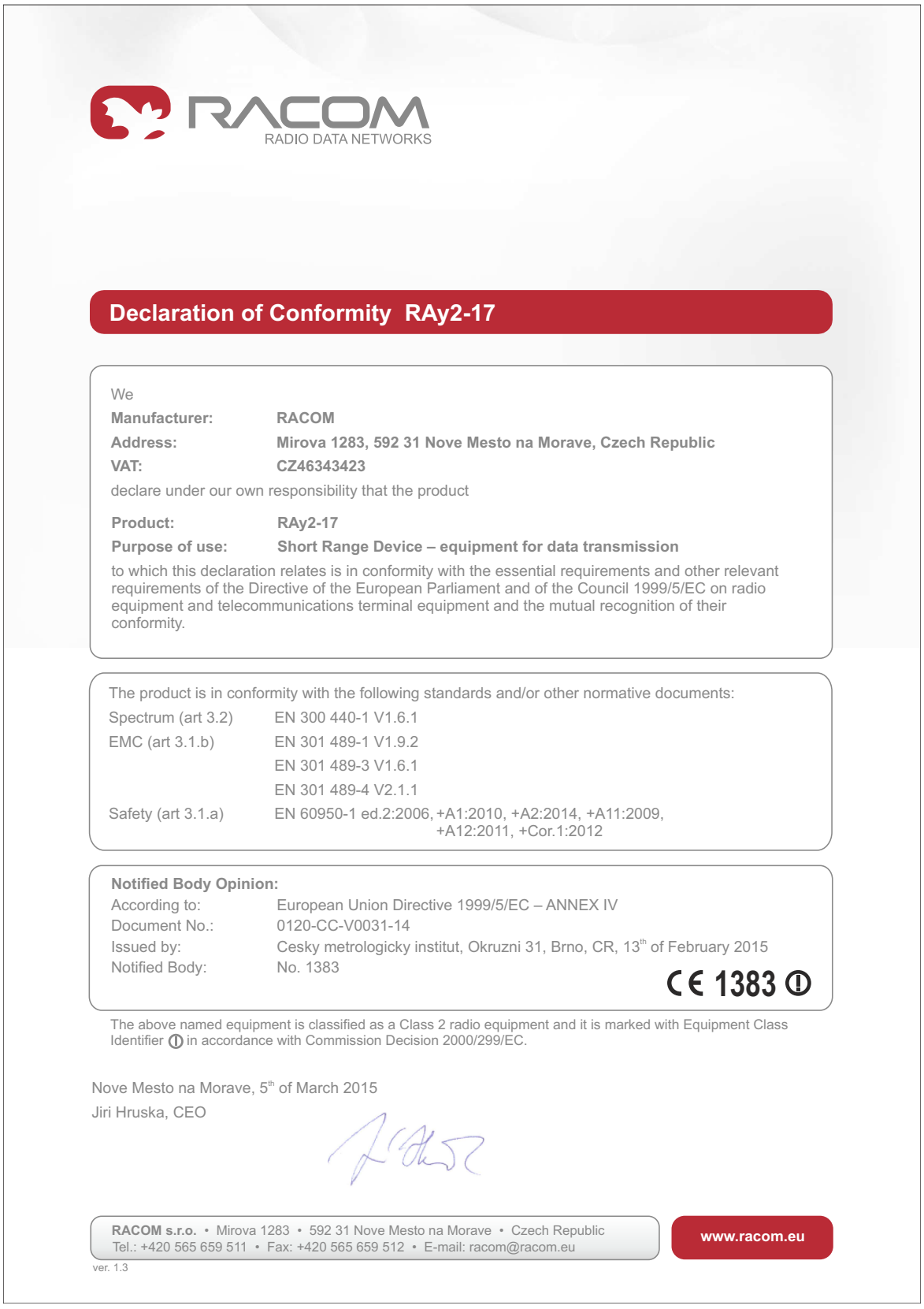
Nove Mesto na Morave, 15th of March 2015
Jiri Hruska, CEO

RACOM s.r.o. • Mirova 1283 • 592 31 Nove Mesto na Morave • Czech Republic
Tel.: +420 565 659 511 • Fax: +420 565 659 512 • E-mail: racom@racom.eu

www.racom.eu

ver. 1.3

Fig. 11.2: Declaration of Conformity for RAy2-11



RACOM
RADIO DATA NETWORKS

Declaration of Conformity RAy2-17

We

Manufacturer: **RACOM**
Address: **Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**
VAT: **CZ46343423**

declare under our own responsibility that the product

Product: **RAy2-17**
Purpose of use: **Short Range Device – equipment for data transmission**

to which this declaration relates is in conformity with the essential requirements and other relevant requirements of the Directive of the European Parliament and of the Council 1999/5/EC on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

The product is in conformity with the following standards and/or other normative documents:

Spectrum (art 3.2)	EN 300 440-1 V1.6.1
EMC (art 3.1.b)	EN 301 489-1 V1.9.2
	EN 301 489-3 V1.6.1
	EN 301 489-4 V2.1.1
Safety (art 3.1.a)	EN 60950-1 ed.2:2006, +A1:2010, +A2:2014, +A11:2009, +A12:2011, +Cor.1:2012

Notified Body Opinion:

According to:	European Union Directive 1999/5/EC – ANNEX IV
Document No.:	0120-CC-V0031-14
Issued by:	Cesky metrologicky institut, Okruzni 31, Brno, CR, 13th of February 2015
Notified Body:	No. 1383

CE 1383 ⓘ

The above named equipment is classified as a Class 2 radio equipment and it is marked with Equipment Class Identifier ⓘ in accordance with Commission Decision 2000/299/EC.

Nove Mesto na Morave, 5th of March 2015
Jiri Hruska, CEO

RACOM s.r.o. • Mirova 1283 • 592 31 Nove Mesto na Morave • Czech Republic
Tel.: +420 565 659 511 • Fax: +420 565 659 512 • E-mail: racom@racom.eu

www.racom.eu

ver. 1.3

Fig. 11.3: Declaration of Conformity for RAy2-17

RACOM
RADIO DATA NETWORKS

Declaration of Conformity RAy2-24

We

Manufacturer: **RACOM**
Address: **Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic**
VAT: **CZ46343423**

declare under our own responsibility that the product

Product: **RAy2-24**
Purpose of use: **Short Range Device – equipment for data transmission**

to which this declaration relates is in conformity with the essential requirements and other relevant requirements of the Directive of the European Parliament and of the Council 1999/5/EC on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

The product is in conformity with the following standards and/or other normative documents:

Spectrum (art 3.2)	EN 300 440-1 V1.6.1
EMC (art 3.1.b)	EN 301 489-1 V1.9.2
	EN 301 489-3 V1.6.1
	EN 301 489-4 V2.1.1
Safety (art 3.1.a)	EN 60950-1 ed.2:2006, +A1:2010, +A2:2014, +A11:2009, +A12:2011, +Cor.1:2012

Notified Body Opinion:

According to:	European Union Directive 1999/5/EC – ANNEX IV
Document No.:	0120-CC-V0032-14
Issued by:	Cesky metrologicky institut, Okruzni 31, Brno, CR, 13th of February 2015
Notified Body:	No. 1383

CE 1383 ⓘ

The above named equipment is classified as a Class 2 radio equipment and it is marked with Equipment Class Identifier ⓘ in accordance with Commission Decision 2000/299/EC.

Nove Mesto na Morave, 5th of March 2015
Jiri Hruska, CEO

RACOM s.r.o. • Mirova 1283 • 592 31 Nove Mesto na Morave • Czech Republic
Tel.: +420 565 659 511 • Fax: +420 565 659 512 • E-mail: racom@racom.eu

www.racom.eu

ver. 1.3

Fig. 11.4: Declaration of Conformity for RAy2-24

11.7. Country of Origin Declaration

RACOM
RADIO DATA NETWORKS

Country of Origin Declaration

Producer:	RACOM s.r.o.
Address:	Mirova 1283, 592 31 Nove Mesto na Morave, Czech Republic
VAT No:	CZ46343423

We, the manufacturer, hereby declare that Country of Origin of the RAy microwave links and its accessories is the Czech Republic, EU.

Part Number	Description
RAy2-10	Unit RAy2-10, 2× Gb Eth
RAy2-11	Unit RAy2-11, 2× Gb Eth
RAy2-17	Unit RAy2-17, 2× Gb Eth
RAy2-24	Unit RAy2-24, 2× Gb Eth

Nove Mesto na Morave, 15 of March 2015
Jiri Hruska, CEO

RACOM s.r.o. • Mirova 1283 • 592 31 Nove Mesto na Morave • Czech Republic
Tel.: +420 565 659 511 • Fax: +420 565 659 512 • E-mail: racom@racom.eu

www.racom.eu

ver. 1.1

Fig. 11.5: Country of Origin Declaration

Appendix A. Antenna dimensions

Example antenna's diameter of 68 and 90 cm. More on www.racom.eu[1].

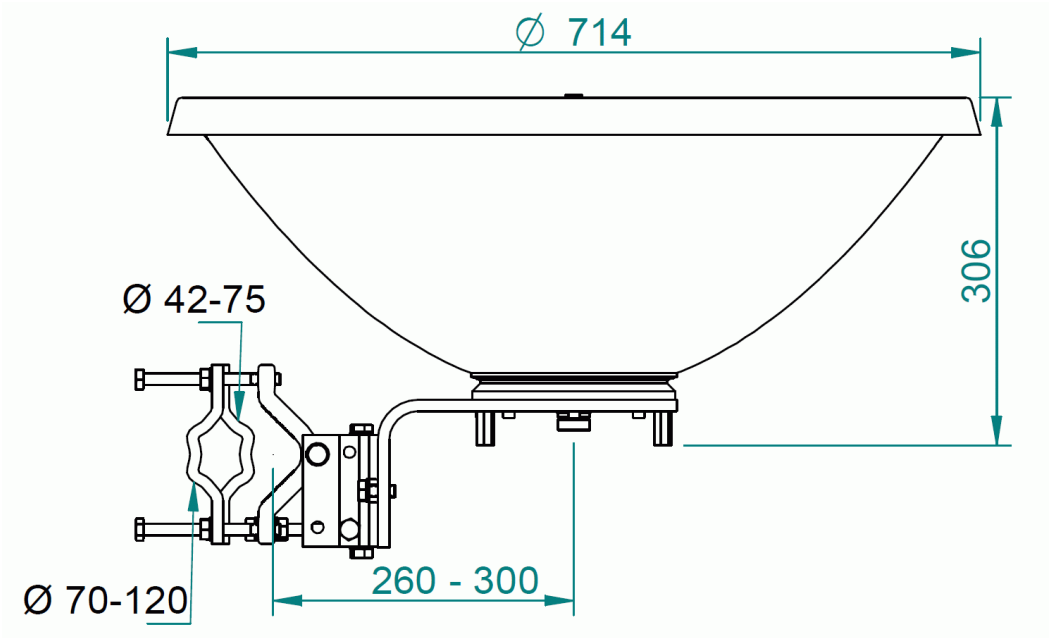


Fig. A.1: Jirous antenna 68

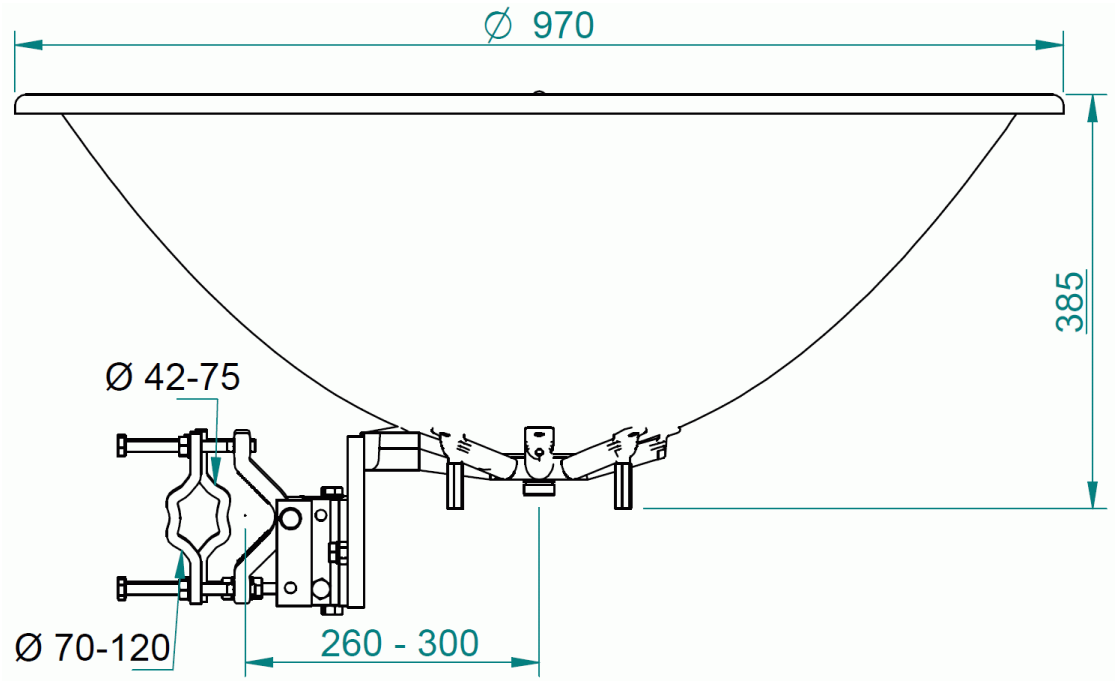
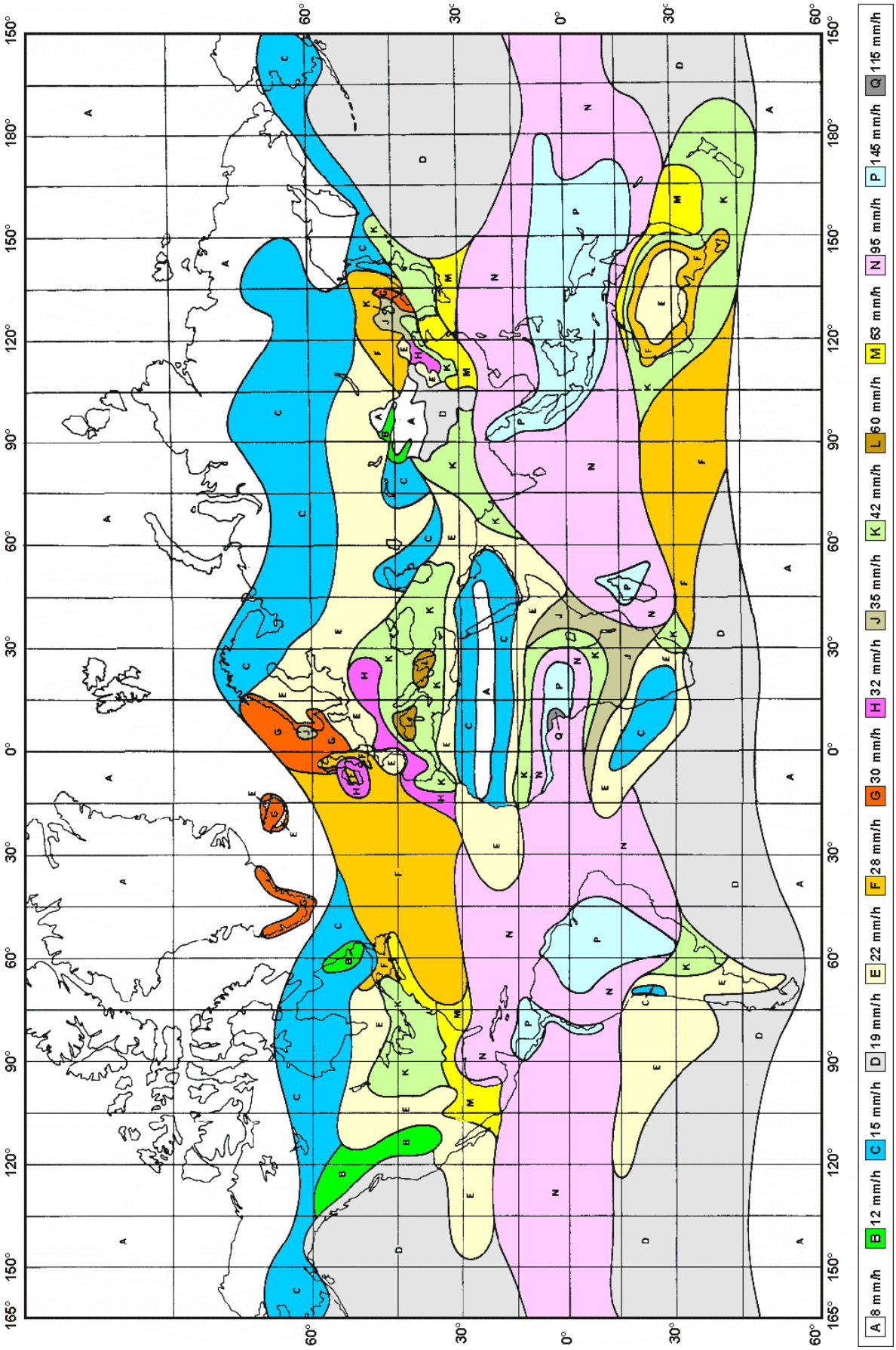


Fig. A.2: Jirous antenna 90

[1] http://www.racom.eu/eng/products/microwave-link.html#download

Appendix B. Rain zone map

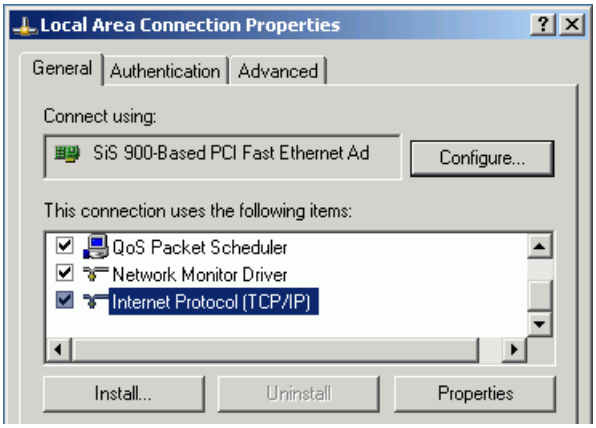


Appendix C. IP address in the PC (Windows XP)

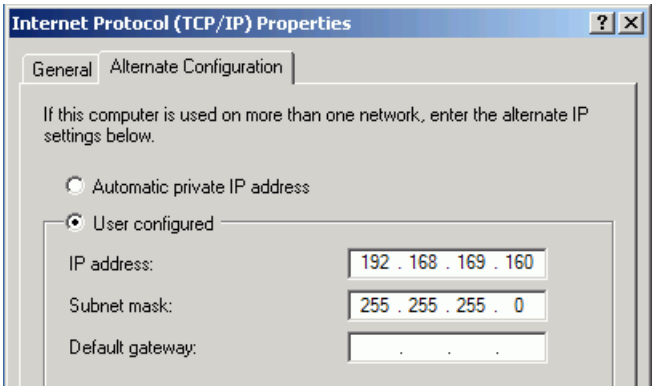
Setting up the IP address in the PC

For configuration of the link a suitable IP address has to be set up in the PC, for example 192.168.169.160

- Open the **Start** menu, **Settings**, **Network Connections**, **Local Area Connection**
- In the window **Local Area Connection** select **Properties**
- Another window opens. Select **Internet Protocol (TCP/IP)** and click **Properties**:



- Another window opens. On the **General** tab select **Use the following IP address**:



- Enter IP Address IP 192.168.169.160
- Set Subnet mask to 255.255.255.0
- Click **OK** to acknowledge these settings and close all windows

Checking the IP address in the PC

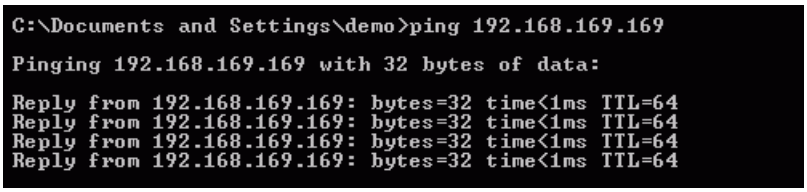
In Windows XP proceed in the following manner:

- Interconnect the configured unit and PC with an Ethernet cable
- Open the Start menu and click **Run...**
- Enter command **cmd**
- Enter command **ipconfig** and read the PC IP address and mask:

Checking the PC - unit connection using Ping

In Windows XP send a ping as follows:

- Check the connection between the PC and the unit via the Ethernet cable.
- In the Start menu click **Run...**
- Enter command **cmd**
- Write **ping 192.168.1.2** and press OK
- A message appears in a window:



If no communication takes place a message appears with the text "Request timed out".

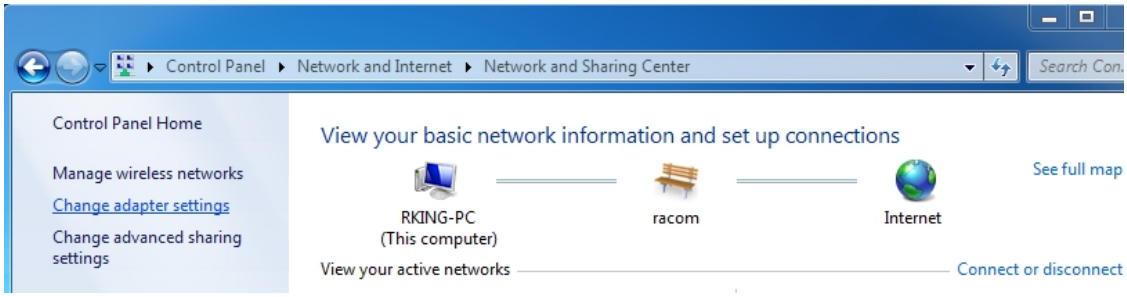
If communication between the web browser and the unit doesn't take place check the browser settings. The *Work offline* item in the *File* menu must not be crossed out.

Appendix D. IP address in the PC (Windows 7)

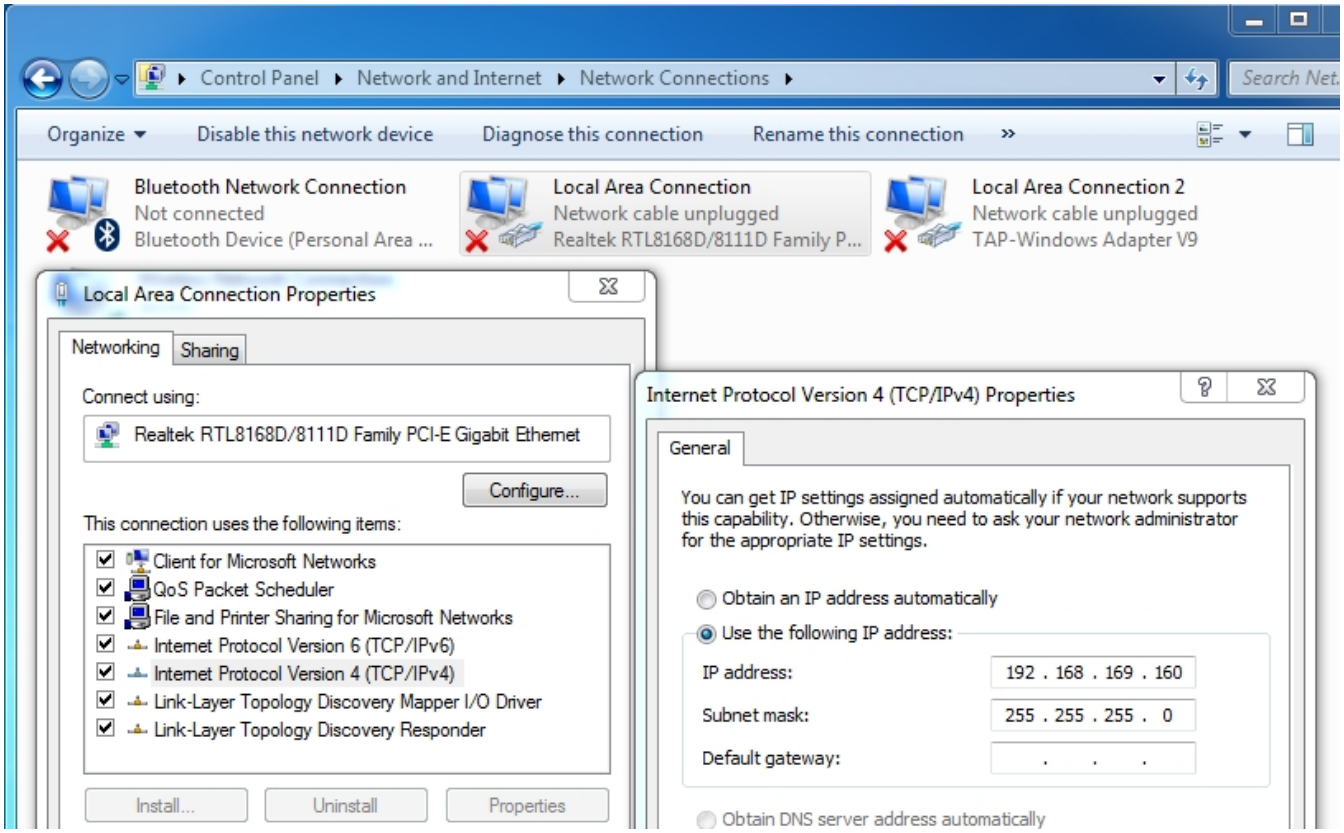
Setting up the IP address in the PC

For configuration of the link a suitable IP address has to be set up in the PC, for example 192.168.169.160

- Open the **Start** menu, **Control Panel**
- In new window choose **Network and Internet**
- Continue **View network status and tasks**
- In new window choose **Change adapter settings**:



- In the Network Connections window, right-click on **Local area connection** and then left-click on **Properties**:



- Select **Internet Protocol Version 4 (TCP/IPv4)** and **Properties**
- On the **General** tab select **Use the following IP address**
  - Enter IP Address 192.168.169.160
  - Set Subnet mask to 255.255.255.0
  - Click **OK** to acknowledge these settings and close all windows

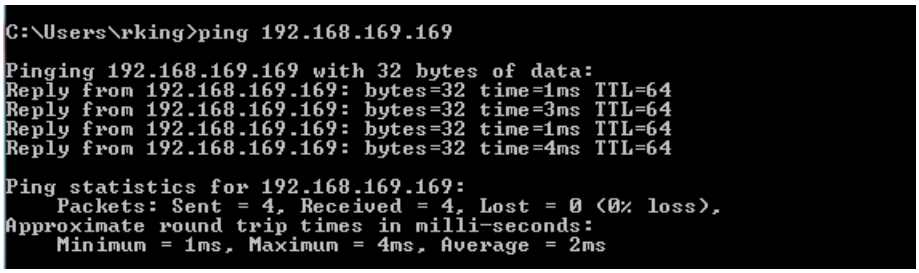
Checking the IP address in the PC

In Windows 7 proceed in the following manner:

- Interconnect the configured unit and PC with an Ethernet cable
- Under the **Start** menu, type the command **cmd** in the *Search programs and files* box and press Enter.
- Inside the *cmd.exe* window that opens, enter the command **ipconfig** at the command prompt and find the information about IP address and mask among the list of messages returned.

Checking the PC - unit connection using Ping

- Check the connection between the PC and the unit via the Ethernet cable.
- Under the **Start** menu, type the command **cmd** in the *Search programs and files* box and press Enter.
- Inside the *cmd.exe* window that opens, type **ping 192.168.169.169** at the command prompt and press Enter.
- Ping times and statistics are returned as shown:



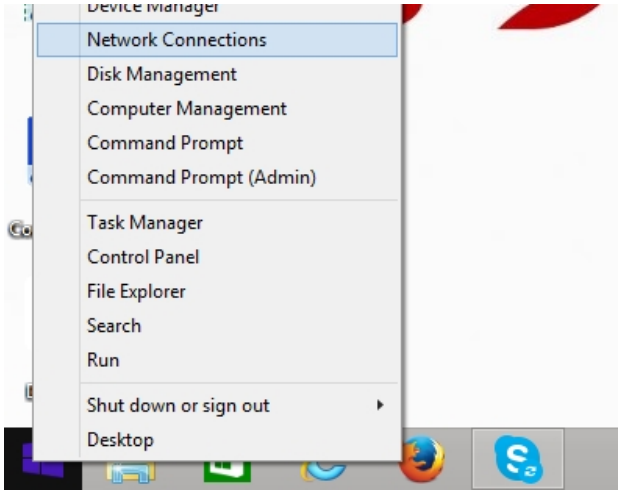
If no communication takes place a message appears with the text *Request timed out*.

If communication between the web browser and the unit doesn't take place check the browser settings. E.g. the *Work offline* item in the *File* menu must not be crossed out.

Appendix E. IP address in the PC (Windows 8)

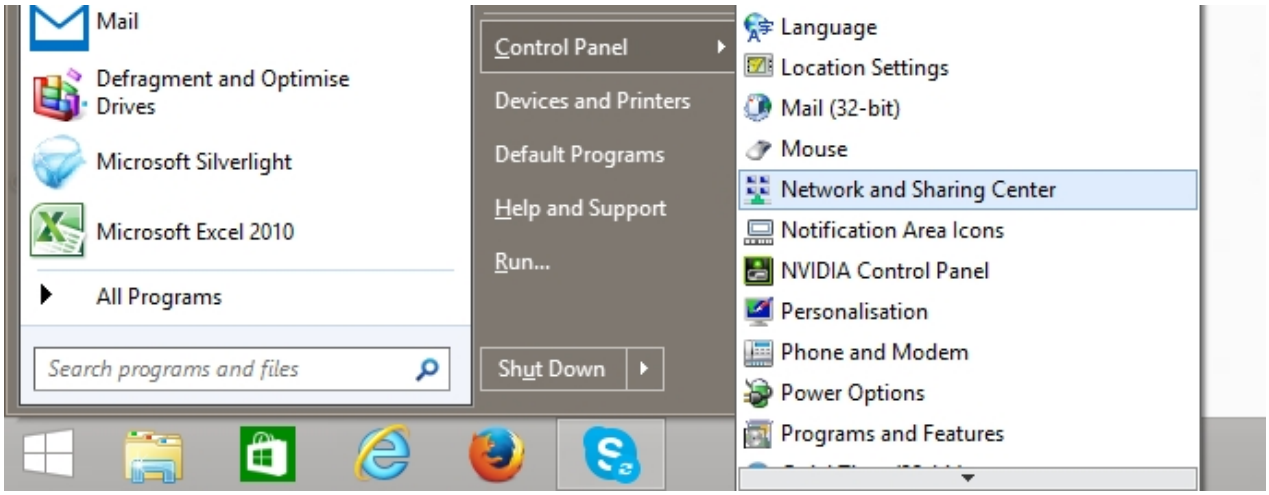
Windows 8 allows you to access the Network Connections page in different ways, for example:

- Using Start Button
  - **Start** button (left down corner), Right click, choose **Network Connections**

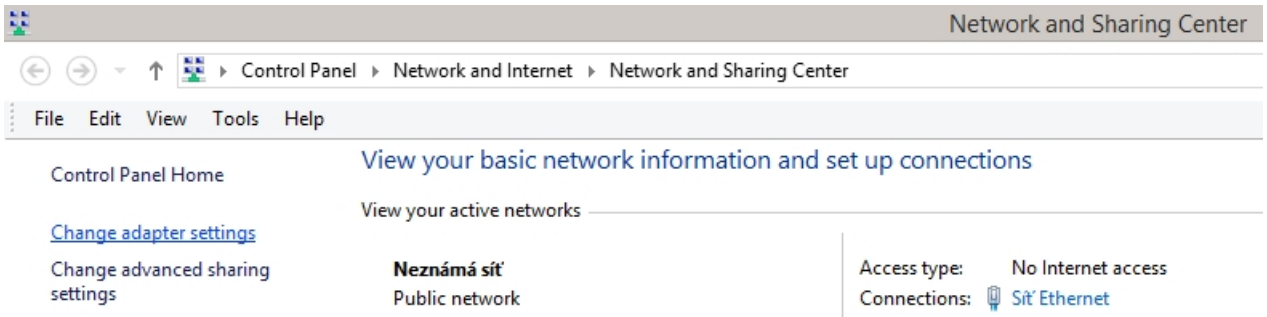


  - Continue to the Network Connections page.

- Using Start Button
  - **Start** button, Left click, choose **Control Panel** and **Network and Sharing Center**



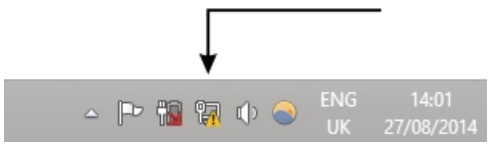
  - Select **Change adapter settings** in the Network and Sharing Center



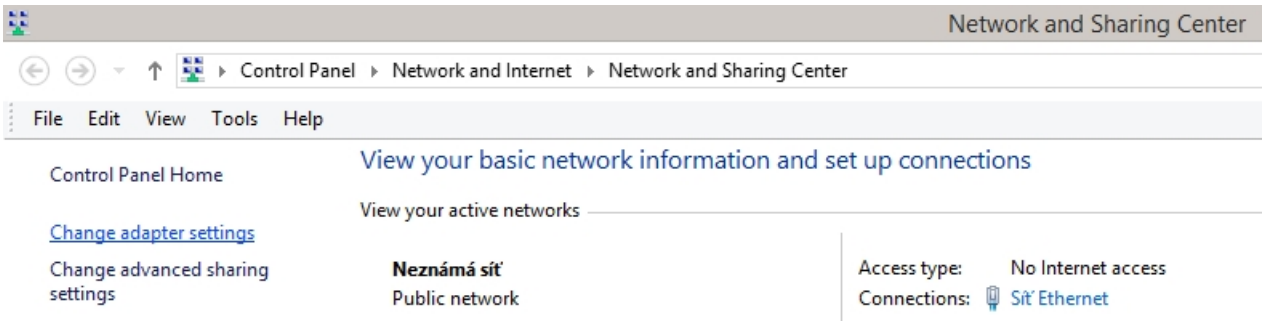
  - Continue to the Network Connections page.

- From Task Bar

- Click the icon for **Internet access** on the task bar in the lower right corner

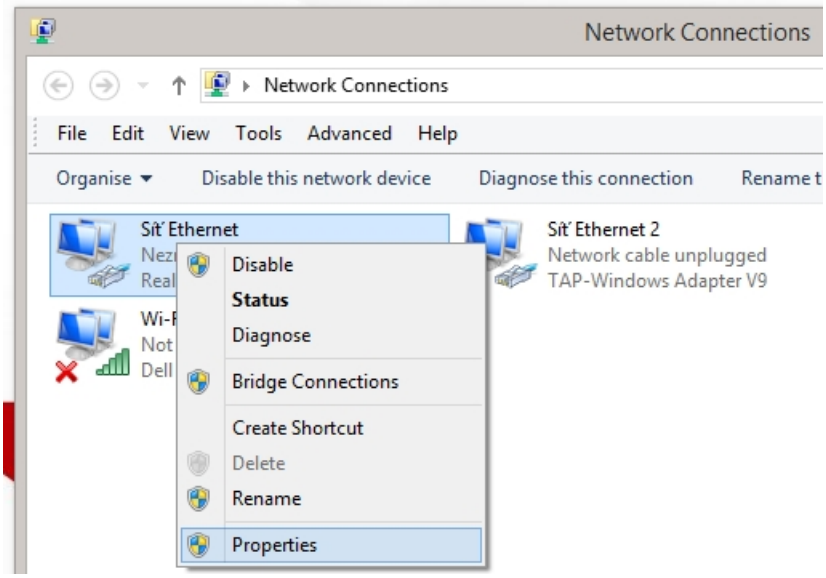


- Select **Change adapter settings** in the Network and Sharing Center

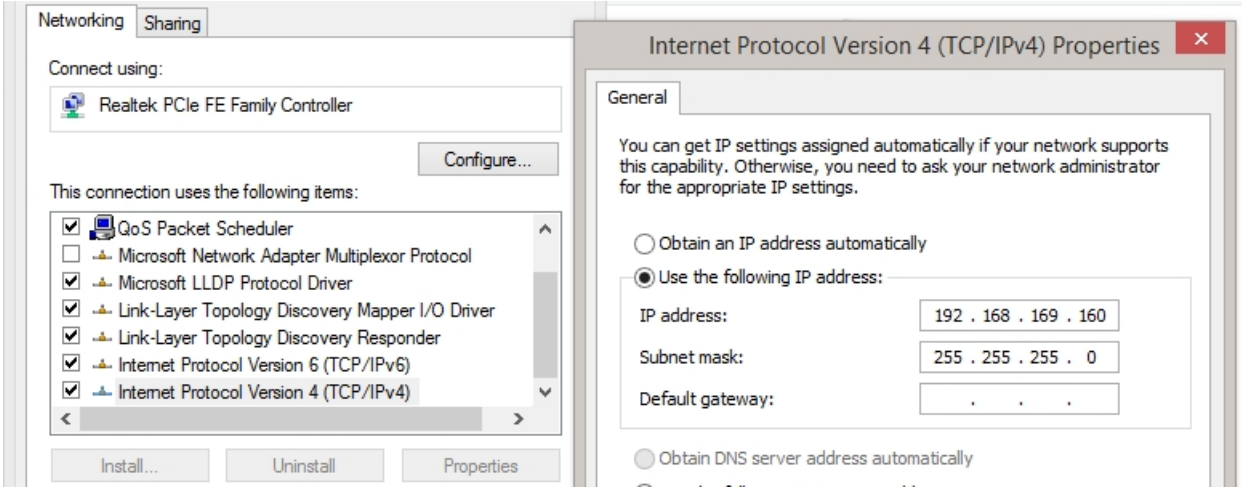


- Continue to the Network Connections page.

- On the Network Connections page:
  - Select **Properties** from **Ethernet Network** drop down menu



  - Choose **Internet Protocol Version 4** (TCP/IPv4), **Properties**, **Use the following IP address**

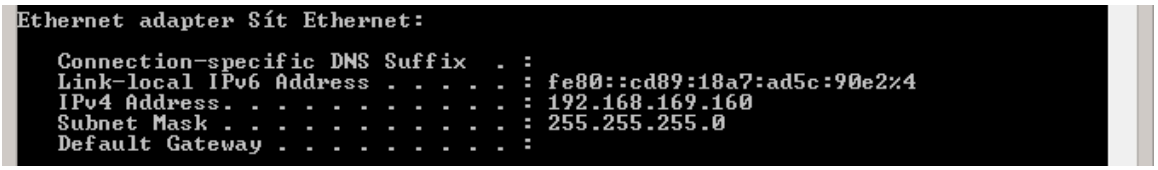


- Enter IP Address 192.168.169.160
- Set Subnet mask to 255.255.255.0
- Click **OK** to acknowledge these settings and close all windows

Checking the IP address in the PC

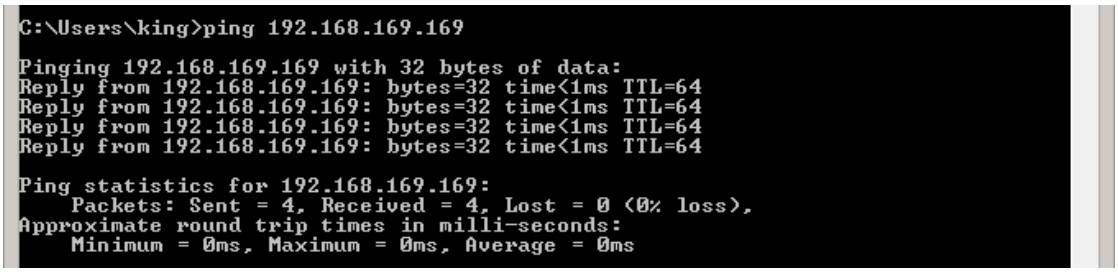
In Windows 8 proceed in the following manner:

- Interconnect the configured unit and PC with an Ethernet cable
- Right click on the **Start** button, type the command **cmd** and press Enter.
- Inside the *cmd.exe* window that opens, enter the command **ipconfig** at the command prompt and find the information about IP address and mask among the list of messages returned.



Checking the PC - unit connection using Ping

- Check the connection between the PC and the unit via the Ethernet cable.
- Right click on the **Start** button, type the command **cmd** and press Enter.
- Inside the *cmd.exe* window that opens, type **ping 192.168.169.169** at the command prompt and press Enter.
- Ping times and statistics are returned as shown:



If no communication takes place a message appears with the text *Request timed out*.

If communication between the web browser and the unit doesn't take place check the browser settings. E.g. the *Work offline* item in the *File* menu must not be crossed out.

Appendix F. SSH key generation

Linux

Use “ssh-keygen” command.

Windows

Use "PUTTYGEN.EXE" software, which is typically located in the c:\Program Files\putty\ directory and apply the "Generate" button.

To use CLI (Command Line Interface) access the unit with a PuTTY client. Access is protected by a key. The key can be in Linux format and it begins:

```
-----BEGIN DSA PRIVATE KEY-----
.....
```

or in PuTTY format which begins:

```
PuTTY-User-Key-File-2: ssh-dss
.....
```

To convert the Linux format to PuTTY do the following:

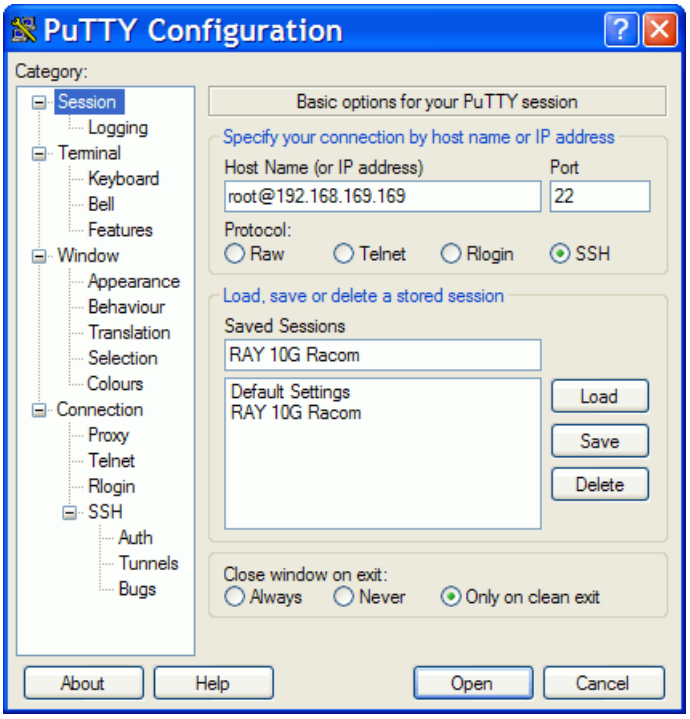
In c:\Program Files\putty\ directory run PUTTYGEN.EXE

Click on “Load” and choose the Linux private key.

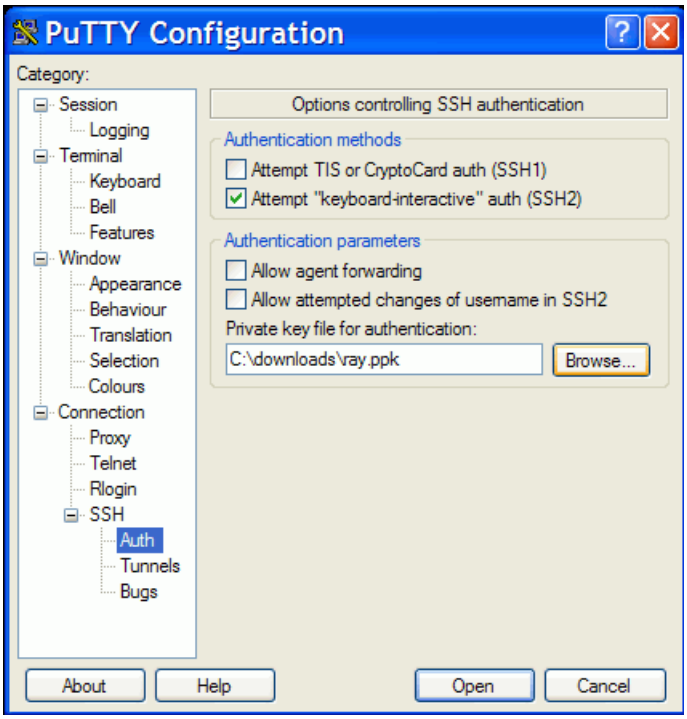
In the next window type your password into the *Key passphrase* and *Confirm passphrase* fields. After that click *Save private key*. Choose location and save the key.

PuTTY access with key

In PuTTY menu fill in the address, e.g. *root@192.168.169.169* and the name of the link, e.g. *RAy 17 Racom*.



Go to *Connection / SSH / Auth* in the left column and locate the key *C:\downloads\ray.ppk*



Go back to *Session* and *Save* the configuration.

To connect select the name of the connection and click *Open*. PuTTY asks for password created during key conversion.

Appendix G. Https certificate

When switching from older versions of the firmware the access certificate for https is changed. New web browser configuration must take place in order to remove the link between the microwave link management IP address and the previous https certificate.

Mozilla Firefox how-to:

1. https certificate
   Remove management IP address from the list: `Tools - Options - Advanced - Encryption - View Certificates – Servers`
   Another possibility: remove certificate Racom “RAy” or Racom “RACOM's product” from the list: `Tools - Options - Advanced - Encryption - View Certificates – Authorities`

2. Upon the new RAy unit connection following message appear: “*This Connection is Untrusted*”.

3. If you are sure that there is no security risk, choose: “*I Understand the Risks*”.

4. The next step is “*Add Exception...*”

5. Finally, you have to “*Confirm Security Exception*”. If the Apply button is not active, it is necessary to perform step No. 1/ and restart web browser.

Internet Explorer may give following message “*There is a problem with this website's security certificate*”. Choose “*Continue to this website (not recommended)*”. The address line gives you status information “*Certificate Error*”. This inconvenience is caused by impossibility to create security certificate valid for list of user selected IP addresses.

Appendix H. Unit block diagrams

Unit overview

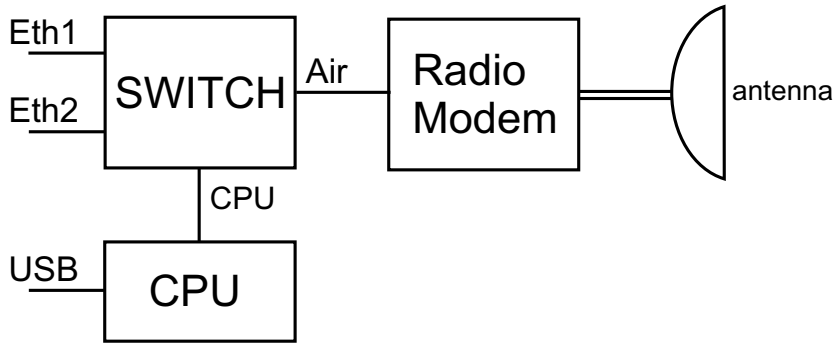


Fig. H.1: Block diagram of the unit

Switch and connected ports

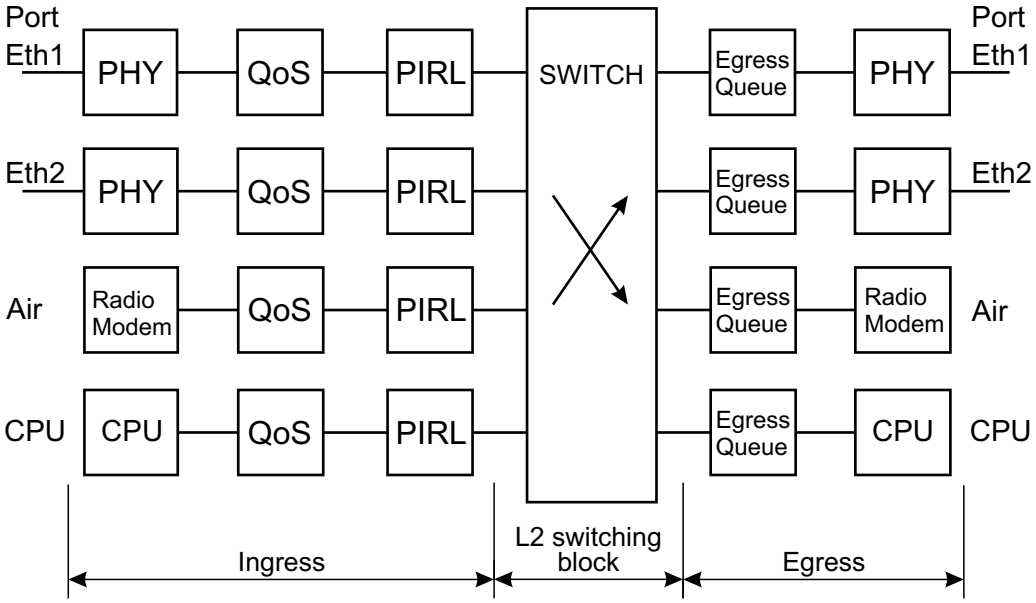


Fig. H.2: Switch and connected ports

Other schemes processing of framework:

Menu PIRL

Menu Advanced

Index

Appendix I. Revision History

Revision 1.0 2014-05-28
First issue

Revision 1.1 2014-06-04
Name plate changes

Revision 1.2 2014-07-15
RAy2-11 C,D user speed and CS correction

Revision 1.3 2014-07-25
Accessory supplemented

Revision 1.4 2014-08-12
RAy2-11 A,B frequency range corrected

Revision 1.5 2014-09-01
Several channels added to RAY2-11 A,B
H/L switching warning
ETH cable grounding
Overview diagram of the unit
IP address setting in Windows 7 and Windows 8 PC

Revision 1.6 2014-09-10
Menu description updated for fw 1.3.3.0.

Revision 1.7 2014-09-12
Changed the Upper channels labeling at RAy2-17, RAy2-24
Changed the Upper channels frequency for 56 MHz bandwidth at RAy2-17, RAy2-24

Revision 1.8 2014-11-24
Added the Switch settings - Advanced menu description

Revision 1.9 2015-03-06
Quick Start Guide - new description
Chapter 1 - the technical parameters table moved to Chapter 10
Directing antennas - the new explanation

Revision 1.10 2015-03-25
Configuration - updated
Declaration of Conformity - updated

Revision 1.11 2015-04-21
USB accessories - updated
Alarm Acknowledge - updated
50 MHz channel on 17 and 24 GHz

Revision 1.12 2015-06-02

- Updated for fw 2.1.7.0.
- Changes in the super user mode
- Order code description
- RAy2-10 radio parameters updated
- Accessories updated

Revision 1.13 2015-12-01

- Updated for fw 2.1.13.0.
- Diagram PIRL improved
- Diagram Advanced added